EPIDEMIOLOGY OF JOCKEY FALLS IN THE THOROUGHBRED RACING INDUSTRY IN AUSTRALIA, 2002/03 TO 2008/09 RACING SEASONS

by

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Declaration of originality

This thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except by way of background information duly acknowledged in the thesis, and to the best of my knowledge and belief no material previously published or written by any other person except where due acknowledgement is made in the text of the thesis, nor does the thesis contain any material that infringes copyright.

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Statement of ethical conduct

The research associated with this thesis abides by the international and Australian codes on human and animal experimentation, the guidelines by the Australian Government's Office of the Gene Technology Regulator and the rulings of the Safety, Ethics and Institutional Biosafety Committees of the University.

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Statement of authorship

This thesis includes papers for which Peta Hitchens (PLH) was not the sole author. PLH was the lead in this research as she completed data collection, analysed the data and wrote the manuscripts. However, she was assisted by the co-authors whose contributions are detailed below.

1. The paper reported in Chapter 3:

Hitchens PL, Blizzard CL, Jones G, Day LM, Fell J. The incidence of race-day jockey falls in Australia, 2002–2006. *Med J Aust*, 2009;190(2):83-86.

The contribution of each author:
PLH was responsible for obtaining approvals, design and conduct of the study, data collection, data management and cleaning, and compiled the initial draft of the manuscript. With CLB, she undertook all the analyses and interpretation of the data, and completed revisions.
GJ helped with analyses and interpretation of the results and revised the manuscript.
LMD helped with analyses and interpretation of the results and revised the manuscript.
JF helped with analyses and interpretation of the results and revised the manuscript.

2. The paper reported in Chapter 4:

Hitchens PL, Blizzard CL, Jones G, Day LM, Fell J. Predictors of race-day jockey falls in flat racing in Australia. *Occup Environ Med*, 2010;67(10):693-698.

The contribution of each author:
PLH was responsible for obtaining approvals, design and conduct of the study, data collection, data management and cleaning, and compiled the initial draft of the manuscript. With CLB, she undertook all the analyses and interpretation of the data, and completed revisions.

GJ helped with analyses and interpretation of the results and revised the manuscript.
LMD helped with analyses and interpretation of the results and revised the manuscript.
JF helped with analyses and interpretation of the results and revised the manuscript.

3. The paper reported in Chapter 5:

Hitchens PL, Blizzard CL, Jones G, Day LM, Fell J. Predictors of race-day jockey falls in jumps racing in Australia. *Accid Anal Prev*, 2011;43(3):840-847.

The contribution of each author:
PLH was responsible for obtaining approvals, design and conduct of the study, data collection, data management and cleaning, and compiled the initial draft of the manuscript. With CLB, she undertook all the analyses and interpretation of the data, and completed revisions.
GJ helped with analyses and interpretation of the results and revised the manuscript.
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The contribution of each author:
PLH was responsible for obtaining approvals, design and conduct of the study, data collection, data management and cleaning, and compiled the initial draft of the manuscript. With CLB, she undertook all the analyses and interpretation of the data, and completed revisions.
JF helped with design and conduct of the study, analyses and interpretation of the results and revised the manuscript.
GJ helped with analyses and interpretation of the results and revised the manuscript.
LMD helped with analyses and interpretation of the results and revised the manuscript.

Signed by first named supervisor, A/Prof Leigh Blizzard:

Signed: ……. Date: ……

Only a Jockey (1887)

Andrew Barton ‘Banjo’ Paterson

‘Richard Bennison, a jockey, aged fourteen, while riding William Tell in his training, was thrown and killed. The horse is luckily uninjured.’ — Melbourne Wire.

OUT in the grey cheerless chill of the morning light,
Out on the track where the night shades still lurk;
Ere the first gleam of the sungod’s returning light,
Round come the race-horses early at work.
Reefing and pulling and racing so readily,
Close sit the jockey-boys holding them hard,
“Steady the stallion there—canter him steadily,
Don’t let him gallop so much as a yard.”
Fiercely he fights while the others run wide of him,
Reefs at the bit that would hold him in thrall,
Plunges and bucks till the boy that’s astride of him
Goes to the ground with a terrible fall.
“Stop him there! Block him there! Drive him in carefully,
Lead him about till he’s quiet and cool.
Sound as a bell! though he’s blown himself fearfully,
Now let us pick up this poor little fool.
“Stunned? Oh, by Jove, I’m afraid it’s a case with him;
Ride for the doctor! keep bathing his head!
Send for a cart to go down to our place with him”—
No use! One long sigh and the little chap’s dead.
Only a jockey-boy, foul-mouthed and bad you see,
Ignorant, heathenish, gone to his rest.
Parson or Presbyter, Pharisee, Sadducee,
What did you do for him?—bad was the best.
Negroes and foreigners, all have a claim on you;
Yearly you send your well-advertised hoard,
But the poor jockey-boy—shame on you, shame on you,
“Feed ye, my little ones”—what said the Lord?
Him ye held less than the outer barbarian,
Left him to die in his ignorant sin;
Have you no principles, humanitarian?
Have you no precept—“go gather them in?”
Knew he God’s name? In his brutal profanity,
That name was an oath—out of many but one—
What did he get from our famed Christianity?
Where has his soul—if he had any—gone?
Fourteen years old, and what was he taught of it?
What did he know of God’s infinite grace?
Draw the dark curtain of shame o’er the thought of it,
Draw the shroud over the jockey-boy’s face.

Abstract

Riding thoroughbred racehorses is a hazardous occupation. This thesis aimed to describe rates of occurrence of falls, injuries and fatalities to licensed jockeys in thoroughbred horse racing, and investigate risk factors associated with falls by jockeys participating in flat races (those without hurdles or fences) and jumps races (those in which the horse is required to jump hurdles or fences) conducted in Australia.

Data on race-day falls were extracted from stipendiary stewards' reports provided by the Principal Racing Authority of each state and territory. Incidence rate ratios were estimated using Poisson regression, and hazard ratios were estimated using Cox proportional hazards regression.

Falls occurred at a rate of 0.42 per 100 rides in flat racing and 5.26 per 100 rides in jumps racing. Fall and injury rates were comparable with those found in the United Kingdom, Ireland, France and Japan. In flat racing, the more severe injuries occurred during the race, but most falls occurred pre- or post-race. In jumps racing, most falls occurred at a jump, with 9.7% of falls resulting in a significant injury.

Factors associated with falls in flat racing during race seasons 2002-03 through 2005-06 were female sex of jockey, being an apprentice jockey, being an amateur jockey, drier tracks, younger horse age, shorter race distance, smaller field size and lower race grade.

Important predictors of falls in hurdle racing during race seasons 2002-03 through 2008-09 were higher club level, greater field size, greater prize money, provisionally licensed jockeys and older jockeys. Important predictors of falls for steeplechase racing were type of jump, provisionally licensed jockeys, jockeys having had previous rides at a meeting, and greater field size.

For early-career jockeys who commenced their apprenticeship during race seasons 2002-03 through 2008-09, fall rates in flat racing were strongly and inversely associated with jockey experience and exacerbated by factors associated with lack of proficiency or inexperience of the horse.

In a pilot study, data were obtained on physiological attributes of jockeys and track-work riders in Tasmania. Important factors found to be associated with falls were lower aerobic and anaerobic fitness, greater muscular strength and power, and riding with the full foot in the stirrup irons compared to riding on the ball of the foot.

In conclusion, key factors associated with falls by and injuries to thoroughbred racing jockeys are horse and rider inexperience, which play a mutually reinforcing role, and competitive racing. The physiological attributes of jockeys may be important also. These findings provide the beginnings of an evidence base for formulating strategies to improve occupational health and safety standards in the Australian thoroughbred racing industry.

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This thesis is dedicated to all the jockeys that have lost their lives or suffered injury or hardship whilst pursing their passion.

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List of abbreviations

ACT	Australian Capital Territory
ARB	Australian Racing Board
BMI	Body mass index
CI	Confidence interval
HR	Hazard ratio
IRR	Incidence rate ratio
MRI	Menzies Research Institute
NSW	New South Wales
NT	Northern Territory
OH&S	Occupational Health & Safety
QLD	Queensland
PRA	Principal Racing Authority
RISA	Racing Information Services Australia
RST	Racing Services Tasmania
SA	South Australia
SD	Standard deviation
SE	Standard error
TAS	Tasmania
UK	United Kingdom
US	United States of America
VIC	Victoria
WA	Western Australia

Publications directly arising from the work described in this thesis

Hitchens P, Blizzard CL, Jones G, Day LM. Epidemiology of jockey falls in Australian thoroughbred racing, *Proceedings of the Third Annual Tasmanian Primary Health Care Research, Evaluation and Development (PHCRED)*, 23 November 2006, pp.14.[Abstract]

Hitchens P, Blizzard CL, Jones G, Day LM. The incidence of race-day jockey falls in Australia during the 2002/3 to 2005/6 racing seasons, *Proceedings of the joint Scientific Meeting of the Australasian Epidemiological Association (AEA) and the International Epidemiological Association (IEA) Western Pacific Region*, 27-29 August 2007, Hobart, Tasmania, pp.70. [Abstract]

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Hitchens P, Blizzard, CL, Jones, G, Day, LM, Fell, J. The incidence of race-day jockey falls in Australia, 2002–2006. *Med J Aust*, 2009;190(2): 83-86.

Hitchens P, Blizzard, CL, Jones, G, Day, LM, Fell, J. Predictors of race-day jockey falls in flat racing in Australia. *Occup Environ Med*, 2010;67(10):693-698.

Hitchens P, Blizzard, CL, Jones, G, Day, LM, Fell, J. Predictors of race-day jockey falls in flat racing in Australia in Proceedings of the World Safety Conference 2010. *Inj Prev* September 2010 Vol 16 Supp 1.[Abstract]

Hitchens P, Blizzard, CL, Jones, G, Day, LM, Fell, J. Predictors of race-day jockey falls in jumps racing in Australia. *Accid Anal Prev*, 2011;43(3):840-847.

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Hitchens P, Blizzard CL, Jones G, Day LM, Fell JW. The incidence of race-day jockey falls in Australia during the 2002/3 to 2005/6 racing seasons, Australian Equine Science Symposium, 4- 6 June 2008, Gold Coast, QLD. Oral presentation.

Hitchens P, Blizzard CL, Jones G, Day LM, Fell JW. Predictors of race-day jockey falls in flat racing in Australia, Safety 2010: 10th World Conference on Injury Prevention and Safety Promotion, 21-24 September 2010, London, UK. Poster presentation.

Hitchens P, Blizzard CL, Jones G, Day LM, Fell JW. Predictors of race-day jockey falls in flat and jumps racing in Australia, International Conference for the Health, Safety and Welfare of Jockeys, 7-8 October 2010, Dubai, UAE. Oral presentation.

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Chapter 1: Introduction

1.1 The thoroughbred horse racing industry

Thoroughbred horse racing is Australia's oldest national sport [1]. It is an important spectator sport, rated as second in popularity among Australians to the Australian Football League (AFL), but higher than motor sports and rugby league [1]. Gambling on thoroughbred horse racing is also popular with $14,433 million in turnover in 2008/09, which was more than the total turnover of harness racing, greyhound racing and sports betting combined [2]. During the 2008/09 racing season, 379 race tracks held 2,681 race meetings with 19,438 races with prize money at stake totalling over $421 million [2]. Additionally, thoroughbred horse racing is a major industry that provides full- or part-time employment for almost 250,000 people in the equivalent of 77,000 full-time jobs, and about 300,000 people have a direct interest as owners [1]. Further information on the Australian racing industry is provided in **Appendix 1A**.

On an international level, Australia (17,065 flat races, 146 jumps races) in 2008 was third to the US (49,951 flat races) and Japan (17,612 flat races) in the number of flat races held, and fifth behind Great Britain (3,366 jumps races), France (2,194 jumps races), Ireland (1,434 jumps races), and the US (168 jumps races) in the number of jumps races held. Australia is third, after the US and Japan, for the amount of prize money that is distributed annually [2].

Racing in different countries is conducted in a manner that is largely the same, but with some differences in rules and regulations (for example, those in relation to use of the whip) and race conditions (for example race distance, track type and types of obstacles in jumps racing). In Australia, flat races range between 800m and 3375m in distance and may be run on turf, dirt, sand or synthetic surfaces. In the United Kingdom and France, the shortest flat race is 1000m and the longest is 4400m, with races run on turf tracks or, during the winter months, on all weather (sand/fibre/binder) tracks [3, 4]. In Australia, jumps races (over hurdles or steeplechase fences) is held from March to September, with race distances ranging from 2600m to 5500m. In the United Kingdom and France, jumps racing is held year round and the distances are longer and vary from 3200m to 7200m [3, 4].

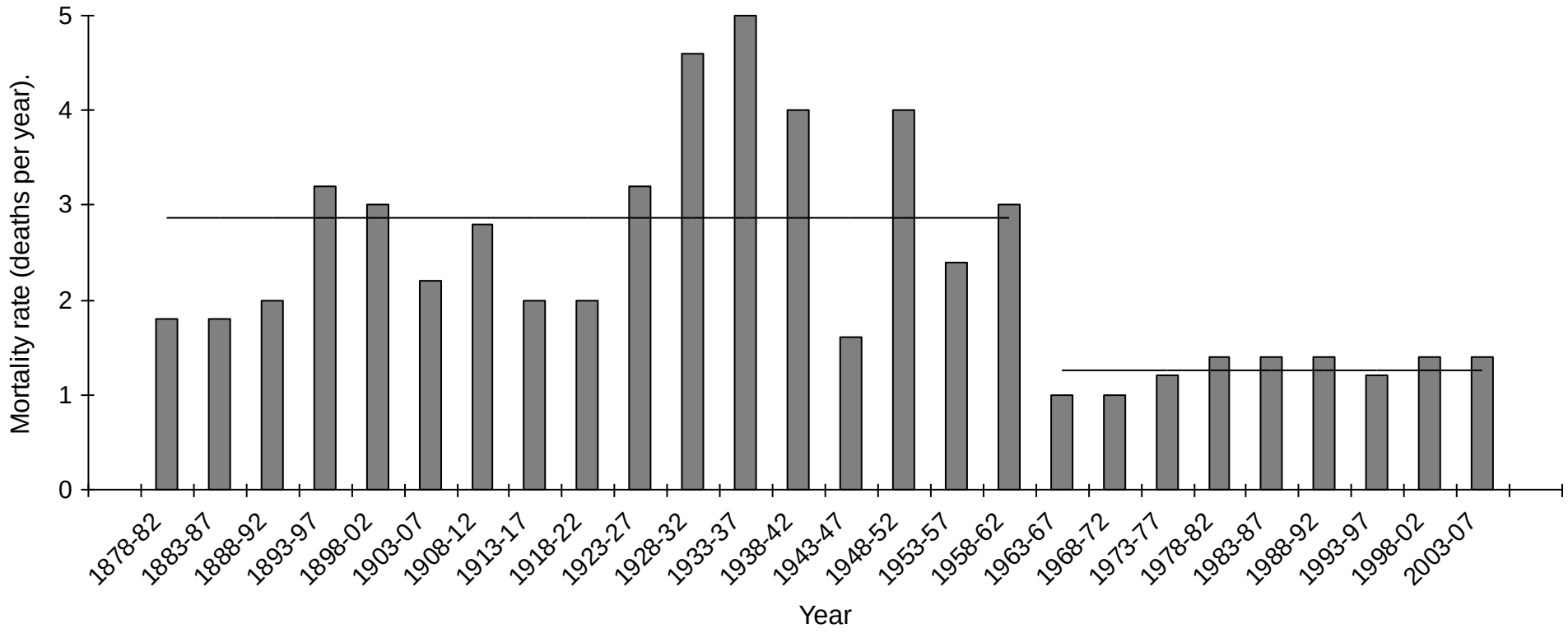
1.2 Deaths to jockeys

Being a thoroughbred horse racing jockey is a dangerous occupation, with a relatively high occurrence of career-ending injuries and death. Comparative mortality studies in the US have found that jockeys had a higher risk of fatality per 100,000 employed than pilots and flight engineers, logging workers, structural metal workers, farm workers, roofers, truck drivers [5], and miners [6], or participants in sports such as skydiving, motorcycling and boxing [7]. Only fishers and related fishing workers had a higher fatality rate [5].

In Australia, there have been 307 fatalities in racing between 1847 and 2010 [8], and this has led to the inference that there are, on average, two jockeys killed annually [9]. **Figure 1-1** depicts the annual occupational fatalities (deaths per year) for jockeys in Australia during the years 1978 to 2007. Occupational fatalities to jockeys occurred at an average rate of 2.31 (95% CI 2.06–2.58) deaths per year during the period, but jockey mortality in the past 25 years of this period stabilised at 1.27 (95% CI 0.98–1.64) deaths per year. Before 1963, the mortality rate was 2.86 (95% CI 2.52–3.24) deaths per year [10]. The method of calculating the mean annual mortality and 95 percent confidence intervals are explained in **Chapter 3** of this thesis.

Deaths to jockeys appear to be less common overseas. In a study of the incidence of fatalities in Great Britain from 1975 to 2000 [3], there were only 4 fatalities in professional flat racing and 5 in professional jumps racing for the entire 26 year period. This was lower than the Australian fatality rate, albeit for a different time period. It translates to a fatality rate of 315 fatalities per 100 million rides. Data were not available for Ireland [3]. In a longer time period from 1975 to 2005, there were 6 fatalities in amateur point-to-point racing in Great Britain at a rate of 1639 fatalities per 100 million rides, which is almost three times higher than that of professional jumps racing in Great Britain (646 fatalities per 100 million rides) [11]. In France from 1975 to 2001, there were 4 fatalities in flat racing (338 fatalities per 100 million rides), and 11 fatalities in jumps racing (2246 fatalities per 100 million rides) from 1980 until 2001 [4]. Although the fatality rate for flat racing was similar to Great Britain, the fatality rate for jumps racing was remarkably higher for reasons that are unclear. In the US, 3 jockeys were fatally injured between 1993 and 1996 [12]. The cause and location of these fatalities were not reported.

Figure 1-1: Jockey deaths in Australia, 1878-2007



Note: Jockey mortality in the past 25 years has stabilised at 1.27 (95% CI, 0.98–1.64) deaths per year. Before 1963, the mortality rate was 2.86 (95% CI, 2.52–3.24) deaths per year.

1.3 Injuries to jockeys

Injury incidence

Injury rates as a result of a fall are high, especially in flat racing. In a study conducted in Victoria, a state of Australia, Cowley *et al.* [13] reported that 75% of injuries sustained by jockeys were as a result of a fall from a horse. However, no denominator data were available to determine injury incidence rates. In a study of jockeys from NSW [14], 39% of falls in flat racing resulted in injury. This was a similar finding to those of the studies in Great Britain, Ireland and France [3, 4]. The percentage of falls in flat races that resulted in injury were similar for France (38.7%), the Republic of Ireland (39.9%), and Great Britain (40.4%). The percentage of falls that resulted in injury were lower for jumps races, but Great Britain had a higher percentage (17.7%) than Ireland (12.3%) or France (13.0%). Oikawa *et al.* [15] reported that in Japan approximately half of all falls occurring during races resulted in an injury. This injury rate is much higher than those of the European studies, which included falls pre-and post-race in addition to those occurring during the race.

Although studies into jockey injuries have been conducted in the United States of America [12, 16, 17], it is difficult to compare the results because no denominator data at the race ride level were reported in order for incidence rates per 100 rides to be calculated. One of the first studies into the incidence of injuries to jockeys was conducted in Seattle from 1970 to 1974, and it was reported that there were 0.024 injuries per race. Waller *et al.* [12] used data obtained from an insurance broker to identify patterns of injury events, and reported that a total of 6,545 injury events occurred during races held between 1993 and 1996 at professional US racetracks involving approximately 2700 jockeys. The estimated annual injury incidence rate was 606 per 1000 jockey years [12]. Press *et al.* [16] conducted a survey of 706 US jockeys that included questions regarding injuries sustained and the cause of the injuries, but did not report incidence rates.

Injury causes and mechanisms

Studies have consistently found that the majority of injuries to jockeys are caused by falls [3, 4, 12-16, 18]. In Australia, Cowley *et al.* [13] reported 358 horse-related injuries sustained by jockeys that rode in Victoria from July 2001 to June 2005, with 75% associated with falls from a horse. In a study on jockeys from NSW from March 2003 to March 2006 [14], almost 60% of injury incidents involved the rider being dislodged. In the

US, between 44.4% and 69% of injuries were caused by the jockey being dislodged from the horse [12, 16]. In the survey conducted by Press *et al.* [16], jockeys reported all factors they believed to be contributory to their injury. For example, the jockey becoming unseated and hitting the running rail in the same incident would be reported as two separate causes, thus making it difficult to determine the primary cause of the injury.

An Australian team [19] conducted a biomechanical analysis of 17 falls by jockeys during races to investigate the injury mechanisms. Video footage was used to obtain estimates of the fall velocity and height, the nature of the impacting surfaces and the impacted body regions. There were a total of 39 individual injuries recorded. They included 7 head injuries (2 of which were fatal), 5 facial injuries, 6 injuries to the neck, 8 injuries to the back or spine, 2 injuries to the shoulder or clavicle, and 3 chest injuries. There were three main injury-producing fall modes observed, including a forward dive into the track as the horse stumbled, a fall from the side of the horse whilst holding onto the reins, and a fall following being pitched into the air or thrown from the horse. In some cases, the rider was trampled or crushed by a fallen horse after hitting the track. The impact velocities observed were in the order of 30 to 50 kph, from heights of up to 3.5 metres. This was the first study of its kind to investigate injury mechanisms, and gives us some insight into how the more severe injuries occur, but its focus was on prevention of the injury rather than prevention of the fall.

Types of injuries

There have been conflicting findings on the most common types of injuries sustained. In Victoria and NSW from 1992 to 2004, a total of 1565 insurance claims by jockeys and track-work riders were received. The most common claims were from injuries to the lower limbs (25%), followed by injuries to the face, head and neck (18%), shoulder injuries (17%), upper limb injuries (15%), and back injuries (14%). Fractures (38%) and sprains/strains (34%) were the most common injury types. However, the data from this study were from claims due to “falls from a height” (the nomenclature used within the insurance data forms), and may not be representative of falls from horses [14]. In another study of Victorian insurance claim data lodged by licensed jockeys, but for the more recent period 2001 to 2005, fractures that were as a result of a fall from a horse accounted for 46% of insurance claims [13]. Similarly, the Victorian study found that the most common location of injuries was to the lower limb (23%), followed by the shoulder (18%) and the upper limb (15%) [13]. Because these data were from insurance claims that are likely to

arise as a result of injuries sufficiently serious to require time off work, soft tissue injuries did not feature prominently.

The earliest known published study into the incidence of injuries to jockeys was conducted in the US from 1970 to 1974 [17]. The authors reported that of the injuries sustained that were captured in that study, 62.7% (64/102) were soft tissue injuries. Soft tissue injuries were also the most common injuries reported in studies from France, Great Britain and Ireland between 1991 and 2001 [3, 4]. Similar to the Australian studies [13, 14], the most common serious injuries that required time away from work were fractures, mainly to the upper limbs and clavicle [3, 4]. Fractures accounted for nearly 50% of insurance claims from 1996 to 2006 in a Great Britain study [20], but shoulder dislocations accounted for the longest time injured and the highest insurance payout. Similarly, in a US survey conducted in 1990, 64% of the 1,757 injuries reported were fractures [16]. In a UK study conducted from 1991 to 2005 [21], the most common types of career-ending injury were fractures, followed by neurological injury to the head and/or spine. Jockeys in France have been reported to have suffered fractures at four times that of their Great Britain colleagues, and also to have had higher rates of dislocations and concussions. The authors speculate that the disparity may be explained by differences in environmental and race conditions such as firmer track conditions or larger field sizes [4], but they do not provide evidence to support this claim.

Waller *et al.* [12] reported that of the injuries sustained by US jockeys in their study of insurance data, 18.8% were to the head or neck, 15.5% were to the legs, 10.7% were to the foot/ankle, 10.7% were to the back, 11% were to the arm/hand, 9.6% were to the shoulder, 4.1% were to the pelvis, and 3.5% were to the chest. A further 16.0% had multiple injuries [12]. Though these figures are similar to results of analysis of insurance data from Australia [14], only 41.8% of the head injuries, 31.9% of the leg and foot injuries, 40.8% of the arm and hand injuries, 55.1% of the back injuries, 49.6% of the chest injuries and 36.2% of the multiple injuries were sustained as a result of a fall from a horse. An earlier US study found that the greatest number of injuries were to the lower extremities (43.1%), followed by upper body injuries (26.5%) and head and neck injuries (15.7%) [17].

It is likely that the survey and insurance data analysed in the US studies [12, 16] and that from Victoria [13] differs to the medical data analysed in the European studies [3, 4, 11,

18] because jockeys are likely to under-report minor injuries, including soft tissue injuries [4].

Cost of injuries to the racing industry

There have been few studies describing the costs of injuries to thoroughbred racing jockeys. However, the limited information suggests that the financial costs related to injuries to jockeys are substantial and impose a sizeable burden on families, the industry, and the nation. In addition, physical and psychological consequences may also result for the jockey and their family and for colleagues involved.

In an Australian study [13] that investigated 985 claims by those employed in racing in the state of Victoria (lodged from July 2001 to June 2005), the analysis revealed significant numbers of injuries among licensed jockeys, track riders and stable hands representing claims costs in excess of AU$6 million per annum. Scaled up to the size of the Australian industry (based on the number of races held in each state or territory in the 2005/06 racing season [22]), this could represent a total annual cost of about AU$25 million. About 26% (257) of these claims were from licensed jockeys and apprentice jockeys, and the mean compensation payout for those jockeys was AU$41,923 for fall related injuries and AU$25,044 for non-fall related injuries [13].

Analyses of insurance data have been published in the UK. One UK study [20] investigated insurance claims from the professional rider's insurance scheme (PRIS), for injuries to professional jockeys that were recorded over an 11 year period (1996-2006). The PRIS provides jockeys with a weekly payment comparable to what they might have been earning from race riding fees if they had not been injured. Any work related accident was covered including those occurring during schooling of horses, transport to and from the racecourse and racing-related activities. The jockeys in this study claimed for 1,328 injuries that resulted in 71,509 days away from racing and a total insurance payout of £4,496,019 (approximately AU$7,100,000), which is about AU$645,500 per annum. On average, each claim resulted in a jockey missing 53.8 days of racing and receiving £3,385.56 (approximately AU$5,900) in compensation. But the authors noted that most injuries were minor in nature, with a third of the jockeys returning to race riding within two weeks of the incident [20]. The average claim from the UK study [20] was considerably lower than the average claim reported in the Victorian study [13].

Another study [21] in Great Britain also analysed insurance payouts from PRIS, but only of jockeys who sustained a career ending injury. Over a 15 year period (1991-2005), there were 45 career ending injuries to jockeys, with a total insurance payout of £2,569,477 (approximately AU$4,480,000), which is about AU$300,000 per annum. Of the 45 injuries, 4 were fatalities with a total of £682,000 (approximately AU$1,190,000) paid out; 41 jockeys received weekly income benefits totaling £1,260,477 (approximately AU$2,200,000); and 6 jockeys received lump sum payments of £627,000 (approximately AU$1,100,000) for permanent disability. The mean insurance payout was similar to the mean payout from the Victorian study [13], at £30,743 (approximately AU$54,000) each to the 41 jockeys receiving weekly income benefits. None of these studies detailed medical costs or indirect costs of injury.

This thesis will not focus on the costs or consequences of falls, injuries and fatalities to jockeys, but it is important to note that there is a paucity of information in this area.

1.4 Falls by jockeys

Fall incidence

There is a paucity of information on falls by jockeys in thoroughbred horse racing and there has not been a national study into the incidence of falls, injuries and fatalities in the horse racing industry. The lack of a national incident or injury recording system has hampered research in this area. However, there have been two state-based studies [13, 14]. The first study [13] was conducted in the state of Victoria and was based on workers compensation claims and injury reports submitted to Racing Victoria Limited (RVL) for the period 2001-2005. Although 75% of injuries occurred as a result of a fall from a horse, no denominator data were available to determine rates of falls. The second study [14] reported falls and injuries ascertained from New South Wales stewards' reports from March 2003 to March 2006. The authors of this study calculated an approximate incidence rate based on an average of 169,485 starters over the three year study period, and reported a race day incident rate for flat racing of 0.29% (0.29 falls per 100 rides) or one incident in every 330 flat race starts.

Substantially higher incidence rates have been reported in international studies. Flat racing fall rates in Europe during 1991-2001 ranged from 0.31 per 100 rides in France, to 0.37 per 100 rides in Ireland, and up to 0.44 falls per 100 rides in Great Britain [4]. The rates

for jumps racing ranged from 4.7 per 100 rides in Ireland, 6.8 per 100 rides in Great Britain, and 9.1 per 100 rides in France [4]. Similarly in Japan from 1998 to 2001, the incidence of falls per rides was much higher in jumps racing (6.68 falls per 100 rides) than in flat racing (0.16 falls per 100 rides) [15], although it should be noted that this study only accounted for falls occurring during the race and not for falls occurring prior to or post-race.

Cowley *et al*. [13] cautioned about extrapolation from international data to Australian racing due to the differences in racing styles, track design, climate, data collection and other variables. McCrory *et al.* [4] also acknowledged the difficulties in comparing injury and fall rates between the three countries in their study (Great Britain, Ireland and France). The authors speculate that the differences in the number of falls between countries may be in part explained by the differences in track conditions or field sizes [4].

Mechanism or cause of falls

The studies conducted in the Australian states of Victoria [13] and NSW [14] did not report the causes or reasons for a jockey falling, and neither did studies from Great Britain [3, 4, 11, 18, 21, 23], Ireland [3, 4, 11, 18], France [4, 18] and the US [12, 16].

In flat racing in Japan from 1998 to 2000, 25.5% of falls were caused by the horse stumbling, 20.1% due to a horse breaking down, 19.0% due to an error by the jockey, 12.2% were involved in a fall by another horse, 11.2% due to interference, 11.1% due to fractious behaviour of the horse and the remainder were unknown causes [15]. In jumps racing in Japan, the majority of falls were due to the horse failing to jump the obstacle successfully (86.8%), and 6.7% of falls were due to involvement in a fall by another horse [15].

1.5 Location of incidents

Studies in Australia [13, 14], the United States [12], and the United Kingdom [3] have investigated the location of injuries, incidents or falls.

A Victorian study [13] investigated falls that resulted in injury. The majority of falls resulting in injury occurred at a race meeting (69%), and the other 31% occurred during track-work. Most falls resulting in injury at race meetings occurred during the race, but 7%

occurred on the way to the starting barrier or after the finishing line [13]. This injury proportion is lower than that reported by other studies, possibly because this study analysed injuries serious enough to trigger workers compensation claims and injury reports submitted to the Principal Racing Authority (PRA) of Victoria (Racing Victoria Limited). It is likely that minor injuries were not completely ascertained in this method of data capture. It is also likely that falls resulting in injury are more likely to be captured at race meetings, and although more time is spent track-work riding, it is likely that the most severe injuries occur at race meetings for example due to the faster speeds in a race, the close proximity of other horses, and jockeys vying for position in a more competitive environment.

A surprisingly high percentage of falls and injuries have been reported to occur prior to the commencement of the race. In a study conducted in NSW [14], it was found that barrier incidents accounted for a total of 27% of injuries, and 35% of injuries were due to the rider being dislodged in the home straight or at the finish line. This is similar to that reported by a study in the US [12] – where 5.8% of injuries occurred prior to or whilst entering the barriers, 15.1% occurred in the barriers, and 14.2% occurred on jump out of the barriers – if the NSW study [14] defined "barrier incidents" as those occurring when entering, standing in and jumping out of the barriers. Most (37.2%) of the injuries occurred during the race, but injuries post-race were not reported. The location of the injury event on the track was not reported for 18.9% of cases [12]. This finding was similar to that of a study from Great Britain and Ireland, in which about 30% of injuries were found to have occurred in the paddock (or 'mounting yard'), before the start, in the stalls (or 'barriers'), or after the finish of a race [3]. It was not reported if these injuries were as a result of a fall, however.

1.6 Risk factors for incidents

There have been no comprehensive studies of risk factors for falls, injuries or fatalities to jockeys in thoroughbred horse racing conducted in Australia or internationally.

In flat racing, differences in fall rates between amateur and professional racing [18] and on different types of track surfaces [3] have been reported. In an investigation [18] of falls by French jockeys from 2000 to 2006 in flat racing, those licensed as professional had a fall incidence rate 0.52 (95% confidence intervals 0.44, 0.62) times lower than amateur

jockeys. In jumps racing, professional jockeys had a fall incidence rate that was 0.74 (95% confidence intervals 0.69, 0.79) times lower than amateur jockeys. In a comparison [3] of flat racing falls on different types of track surfaces in Great Britain from 1994 to 2000, it was reported that there was a fall rate of 0.28 falls per 100 rides on all-weather tracks and a much higher fall rate of 0.42 falls per 100 rides for jockeys riding on turf tracks. Confidence intervals were not reported in this account.

In the only previous study to investigate higher rates of falls by jumps jockeys in Great Britain and Ireland, there was no significant difference reported between the fall/ride ratio of elite jump jockeys (those winning more than 100 races per season) and the average fall/ride ratio of 16.0 [3]. There have been studies of factors associated with falls by horses [24-32], but only around one-half of falls by jockeys accompany a fall by the horse [10], and it is not known whether the risk factors for falls by horses are representative of those for falls where the jockey is dislodged.

There have been no previous studies of falls by horses in flat racing, but there have been studies conducted of falls by horses in jumps racing in Australia as part of jumps racing safety reviews [30-32], and in the UK [24-29]. In the Australian studies, jumps race type (steeplechase races having a higher fall rate than hurdle races), longer race distance, larger field sizes, horse age, weight carried, higher performing horses, horses having had a prior fall, races conducted in autumn and spring compared to those conducted in winter [31], the position of the jump in the race, the horse losing ground during the race, and the horse being pushed during the race [32] were found to be associated with an increased incidence of horse falls. Factors found to decrease risk were races run for a longer duration, races run at faster speeds, races conducted later in the period between 1995 and 2006, and the Mark 3 steeplechase fences compared to the 'old' fences [31]. Factors identified as contributors to horse falls in the UK include larger field size [24, 26, 29], race distance [24, 25], track [28, 29] and weather conditions [28], the position of the jump in the race [25], the speed of the race [25], close proximity to other horses [27, 28], the number of jumps, distance between jumps, incline of the track in the vicinity of the jump [26], horse age [24, 28], higher official rating [25] that is similar to the Australian handicap rating, longer odds (greater starting price) in the Grand National steeplechase [29], greater prize money [25], inexperience of the horse as indicated by number of previous race starts or lack of previous experience of the course [25, 26, 29], travel time to races [28], use of visors on horses [24], and use of the whip [27]. The factors contributing to falls in each jurisdiction are

generally similar, and differences may be attributed to the differences in jumps racing practices. Jumps racing in the UK is markedly different to that in Australia because there are substantially more jumps races held in the UK, the UK races are longer in distance (the minimum distance is 3200 metres for novice hurdlers and the maximum is 7200 metres in the 'Grand National' at Aintree), the horses are older (the oldest horse in our study was 12 years of age), the fences are higher, and steeplechase races may include ditches and water jumps [25, 26]. Furthermore, most jump horses (75%) in the UK are trained exclusively for jumps racing [33] and, by contrast, only 1% of jump starts in Victoria are by horses that have never started in a flat race, with horses having an average of 33 prior flat starts before commencing their jumps career [34].

Additionally, studies of injuries to riders in equestrian and recreational settings have pointed to some risk factors that may be important. Younger age [35] and fractious behaviour [36, 37] of the horse have been associated with injury occurrence. Sex and experience of the rider play a part in a context-dependant manner, with injuries more common among young [35, 37-40] or novice [36, 40-43] and mainly female [37-40, 44, 45], riders but also among older [39, 44] experienced riders in high-level competition events [46, 47]. Other factors linked with injuries have been warmer months [37], but possibly only because more recreational riding occurs at these times, and the height of the horse [35] that can vary from pony-size to thoroughbred-size or greater. However, for the most part, these findings have little relevance to falls and injuries to licensed jockeys in thoroughbred horse racing. What is needed is a study of risk factors particular to thoroughbred horse racing jockeys.

1.7 Summary

Working as a licensed jockey in thoroughbred horse racing is a high-risk occupation. Injury and death rates for thoroughbred racing jockeys have been reported previously in studies conducted in Great Britain [3, 4, 11, 18, 21, 23], Ireland [3, 4, 11, 18], France [4, 18], the United States of America [12, 16, 17] and Japan [15]. These studies have consistently found that the majority of injuries are caused by falls [3, 4, 12-16, 18]. No national study of jockey falls has been undertaken in Australia, but there have been reviews of injuries to jockeys in Victoria [13] and in New South Wales [14]. Those studies have provided estimates of incidence rates but only for those states and, in the case of the Victoria study [13], using a data capture method that may not have provided complete

ascertainment. Furthermore, there has been no investigation of factors associated with falls to jockeys in flat or jumps racing. The design of interventions to prevent falls by jockeys in thoroughbred horse racing requires an understanding of the factors that are associated with these falls. However to do this, data on falls and injuries to jockeys in Australia need to be collated, preferably on a national level, and investigated in a thorough manner to provide evidence-based recommendations.

1.8 Research aims and objectives

General aim

The primary aim of the investigations reported in this thesis was to describe rates of occurrence of falls, injuries and fatalities to licensed thoroughbred racing jockeys, and to investigate risk factors associated with falls by jockeys participating in flat and jumps races conducted in Australia.

Specific objectives

The specific objectives of this investigation were:

1. To investigate the incidence of falls, injuries and fatalities to licensed thoroughbred racing jockeys in Australia.
2. To monitor trends of falls, injuries and fatalities during the study period.
3. To make comparisons of fall, injury and fatality rates between Australia and other countries.
4. To identify risk factors for falls by jockeys in flat racing in Australia.
5. To identify risk factors for falls by jockeys in jumps racing in Australia.
6. To study the specific contribution of jockey inexperience to falls.
7. To make recommendations about possible strategies to reduce the risks identified.
8. To identify areas requiring further research in this field.

1.9 Thesis outline

In brief, the structure of the thesis can be described as follows:

Chapter 1: Introduction.

This chapter provides the context for the investigation reported and describes the aims and the structure of the thesis. An introduction to the literature on falls, injuries and fatalities to jockeys in the thoroughbred horse racing industry is provided. **Appendix 1A** provides additional information on characteristics specific to Australian racing.

Chapter 2: Methods.
This chapter describes the methods of data collection, database design and data analysis used in this investigation of falls by jockeys in Australian thoroughbred horse racing initially during the period 1 August 2002 to 31 July 2006. Subsequently, the database was expanded to include races conducted during the period 1 August 2006 to 31 July 2009 to allow more powerful analysis of falls in jumps racing (**Chapter 5**) and the contribution of jockey experience to falls (**Chapter 6**). The database is the first comprehensive collection of incident information on falls and injuries to licensed jockeys at Australian thoroughbred race meetings to be collated and analysed.

Chapter 3: The incidence of race-day jockey falls in Australia, 2002-2006.
This chapter describes the rates of occurrence of falls, injuries and fatalities to licensed thoroughbred racing jockeys in Australia and compares the incidence rates with those of other countries for which similar estimates are available. The contents of this chapter have been published in a peer-reviewed journal [10].

Chapter 4: Predictors of race-day jockey falls in flat racing in Australia.
This chapter investigates risk factors associated with falls by licensed thoroughbred racing jockeys participating in flat races conducted in Australia between 1 August 2002 and 31 July 2006. The contents of this chapter have been published in a peer-reviewed journal [48].

Chapter 5: Predictors of race-day jockey falls in jumps racing in Australia.
This chapter investigates risk factors associated with falls by licensed thoroughbred racing jockeys participating in jumps races conducted in Australia between 1 August 2002 and 31 July 2009. Additional analyses are presented in **Appendix 5A**. The contents of this chapter have been published in a peer-reviewed journal [49].

Chapter 6: The association between jockey experience and race-day jockey falls in flat racing in Australia.
This chapter describes the rates of occurrence and risk factors for falls to apprentice thoroughbred racing jockeys in flat racing in Australia who commenced their race riding career between 1 August 2002 and 31 July 2009. A report based on the material presented in this chapter will be submitted for publication in a peer-reviewed journal.

Chapter 7: Are physiological attributes of jockeys predictors of falls? A pilot study.
This chapter describes a pilot study of the physiological attributes of jockeys and track-work riders in Tasmania and investigates whether these attributes are associated with falls. Testing protocols and supporting documentation are presented in **Appendix 7A to 7F**. The contents of this chapter have been published in a peer-reviewed journal [50].

Chapter 8: Summary.
This chapter summarises the important findings, implications and conclusions from this study and presents recommendations for future research.

1.10 Postscript

This chapter has presented an introduction to the literature relevant to falls, injuries and fatalities to jockeys in the thoroughbred horse racing industry and has described the objectives and structure of the thesis. In the next chapter, methods for data collection, database design and data analysis of Australian thoroughbred racing incident data and denominator data from 1 August 2002 to 31 July 2009 are described.

1.11 References

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Appendix 1A: The thoroughbred racing industry in Australia

1A.1 Thoroughbred racing in Australia

The professional thoroughbred racing season in Australia takes place between 1 August and 31 July each year. Only three states - Victoria, South Australia and Tasmania - conducted jumps racing (either steeple or hurdle) during the study period. Tasmania discontinued jumps racing following the 2006/07 racing season.

Flat races range between 800m and 3375m in distance and may be run on turf, dirt, sand or synthetic surfaces. Jumps races range from 2600m to 5500m in distance, are run on a turf surface and can be over either hurdles or steeplechase fences.

The number of races on the flat and over jumps in Australia during 2002-09 are shown in **Table 1A-1**.

Table 1A-1: Number of flat and jumps races held in Australia, 1 August 2002 to 31 July 2009 [1-7].

	Flat	Jumps	Total
2002/03	20,525	177	20,702
2003/04	19,921	151	20,072
2004/05	19,828	140	19,968
2005/06	19,821	142	19,963
2006/07	19,382	163	19,545
2007/08	17,065	146	17,211
2008/09	19,326	112	19,438
Total	135,868	1,031	136,899

1A.2 Australian Rules of Racing

The Australian Rules of Racing have been in place for almost a century and prescribe accepted practices, conditions and integrity standards for racing throughout Australia [2]. These rules are administered by the Principal Racing Authority (PRA) of each state or

territory, each of which also has their own set of local rules. The PRAs in each state and territory are the NSW Thoroughbred Racing Board, Racing Victoria Limited, Queensland Racing Limited, Racing and Wagering Western Australia, Thoroughbred Racing S.A. Limited, Thoroughbred Racing NT, Tasmanian Racing Board and Canberra Racing Club Incorporated [8].

1A.3 The role of the stipendiary steward

Stipendiary stewards are employed by the PRAs to regulate racing. In matters pertaining to safety and welfare, their powers include conduct of inquiries, punishment of any person committing a breach of the rules, drug testing of horses and jockeys, standing down of any rider at their discretion, prohibiting any horse from starting in any race, ordering the removal from any horse of any unsafe or non-approved equipment, ordering any rider to alter the length of his/her stirrups, and postponing any race that may be run under unsafe conditions [8].

Stewards' reports are completed following each race meeting. These reports generally contain information on the racetrack, date, officials on duty, track condition, weather, penetrometer reading of water content in the track surface, race name, race distance and number of starters. The report contains a description on each race detailing late scratchings, changes of rider, incidents occurring and the outcomes of those incidents (including falls by horses and/or jockeys), and the outcome or adjournment of inquiries. However, there is not a nationally-applied standardised form of reporting.

1A.4 The thoroughbred racehorse

The average thoroughbred racehorse is 16 hands high (160cm), weighs 500 kilograms and can travel at speeds of up to 60-65 km/hr [9-12]. Race horses tend to be unpredictable animals that can be aroused or frightened by crowd noise, the presence of the jockey on its back, the use of the whip, and the close proximity of other horses. In addition, racing is conducted in a competitive fashion with jockeys striving to obtain the best position for their horse.

The number of thoroughbreds registered to race in Australia during 2002-09 are shown in **Table 1A-2**.

Table 1A-2: Registered thoroughbred race horses in Australia, 1 August 2002 to 31 July 2009, by state/territory [1-7].

	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09
NSW/ACT	10,710	10,750	10,645	10,824	10,753	8,963	10,977
VIC	9,539	9,667	9,315	9,485	9,335	8,987	9,224
QLD	8,564	8,255	8,291	8,217	8,314	7,365	8,160
SA	3,188	3,241	3,152	3,177	3,268	3,061	3,033
WA	3,163	3,234	3,307	3,366	3,540	3,622	3,806
TAS	1,010	1,024	1,008	1,009	1,093	1,136	1,118
NT	584	564	538	575	587	595	615
Total	31,639	31,126	31,037	31,248	31,419	29,972	31,659

1A.5 The jockey

In Australia there are four licence categories for jockeys: full-licence (professional), apprentice, amateur, or cross-country (jumps). The number of jockeys licensed to ride in Australia during 2002-09 are shown in **Table 1A-3**.

Jockeys that hold a full-licence are professional jockeys and do not have any restrictions on where they ride, although they will generally be required to obtain a permit to ride if riding at a race meeting in another state or territory. Prior to obtaining a full-licence, all jockeys in Australia must complete an apprenticeship and are indentured to a trainer (their 'Master'). This apprenticeship will typically take 4 years to complete. The time that an apprentice commences race riding is dependent on each individual's progress. All PRAs require an apprentice to pass a specified number of barrier trials conducted in the presence of the stipendiary stewards prior to being cleared to ride in official races [13-16]. The apprenticeship includes completion of the nationally accredited training scheme, the RGR40202 Certificate IV in Racing (Jockey). Apprentices study stable management, horse health, race riding, literacy and numeracy, drug awareness, diet and nutrition, information technology, financial planning, media protocol, personal health and fitness, and first aid [17]. Amateur jockeys cannot ride at a professional flat race meeting, and are licensed to ride only at picnic or amateur race meetings. In jumps racing, jockeys are classified by cross-country licence (Licence A or Licence B). Jockeys holding a Licence A may ride in any jumping race conducted by a registered race club including those in

metropolitan and surrounding areas, whereas jockeys holding a Licence B may ride in jumping races at country race meetings only.

Table 1A-3: Jockeys licensed to ride in Australia, 1 August 2002 to 31 July 2009, by state/territory [1-7].

	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09
NSW	427	447	250	260	265	258	264
VIC	342	306	271	187	285	296	217
QLD	284	284	284	261	269	274	300
SA	57	70	60	57	46	54	56
WA	119	135	110	103	119	122	115
TAS	33	38	37	43	37	31	33
NT	26	29	22	26	24	21	27
ACT	19	15	9	7	9	9	0*
Total	1,307	1,324	1,043	944	1,054	1,065	1,012

*ACT figures were counted in NSW.

1A.6 Medical standards

The PRAs have set guidelines for medical supervision on race days. At every race meeting at least one ambulance is required to be in attendance. Generally, there are two ambulances on the course at all metropolitan and provincial race meetings. One of the ambulances will follow the field of horses during a race. In addition to the ambulances, there are two or three doctors present [18].

At present, there is no national incident or injury recording system. The Australian Racing Incident Database (ARID) has been established, but it is not yet operational on a national basis [19].

1A.7 Protective and safety equipment

There are rules in place under the Australian Rules of Racing that prescribe the nature and correct use of safety equipment. A helmet must be replaced by the rider when a period of 5 years has expired since its date of manufacture, or if it sustains a severe impact, or if the wearer suffers from concussion following a fall. The current standards of helmets include

AS/NZS 3838 2003: United States Standard (US) ASTM F11 63-01; British Standards (BS) EN 1384/1996 onwards [8]. Approved footwear must be worn, and saddles must be equipped with safety irons or race irons of a design approved by the stewards [8]. In Australia, body protectors have been mandatory since 1999. The protector must meet stringent safety standards as prescribed by the Australian Racing Board [8].

In their local rules and policies, PRAs impose other safety measures. These include maximum field limits on specific racetracks, restrictions on racing uncompetitive, unruly or wayward horses that require those horses to trial satisfactorily prior to racing, a "lightning policy" that requires race meetings to be abandoned under severe weather conditions, and prohibitions on the use of on-course saunas.

1A.8 References

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Chapter 2: Methods

2.1 Preface

In the previous chapter, I presented an introduction to the literature relevant to falls, injuries and fatalities to jockeys in the thoroughbred horse racing industry and described the objectives and structure of the thesis.

In this chapter, methods for data collection and database design, and for analysis of Australian thoroughbred racing incident data from 1 August 2002 to 31 July 2009, are described. The specific methods for data collection and data analysis for the pilot study on physiological attributes of jockeys and track-work riders are in **Chapter 7**. A summary of the methods specific to each study reported in **Chapters 3** to **7** are presented in each chapter.

2.2 Data collection

Falls data

Incident data on falls of licensed jockeys from riding registered racehorses at race meetings throughout Australia were collated through a search of electronic stewards' reports provided by each Principal Racing Authority (PRA). These covered the period from 1 August 2000 to 31 July 2009. Initially, I approached the Australian Racing Board (ARB), Racing Information Services Australia (RISA) and the Principal Racing Authority (PRA) representing each state or territory of Australia for access to incident and race data. I was advised that there was no national collation of incident data and that the most comprehensive means of collating incident data would be to search descriptions of incidents within stipendiary stewards' reports. These reports are published, in most cases electronically, by each PRA following a race meeting.

The stewards' reports were collected and electronically imported into an Access database. An import form was created within the database so that information from the stewards' reports, which follow a set format, could be electronically scanned from the report and imported into their respective fields.

These fields included:

- Date of race
- Name of race club
- Weather conditions
- Track rating and changes in track conditions
- Penetrometer reading (if available)
- Changes in riding engagements
- Race number, name and distance
- Description of factors affecting the race, including horse scratchings, incidents in running and inquiries.

The import form was customised for each PRA to account for slight differences in stewards' report document layout and file format (eg. pdf, html, word).

There was a substantial amount of data cleaning and cross-checking required during verification of the scanned data. This included searching for missing falls data and entering the required information if available, re-entering fields that contained invalid information and manually entering stewards' reports that failed to import correctly. For falls that occurred during the race, the data that were obtained via a search of stewards' reports were verified against the race field data (see following). Where the results indicated that the horse fell, failed to finish or lost its rider, I verified that there was a corresponding entry within the relevant stewards' report.

The incident data were extracted by conducting a keyword search of the stewards' reports. Keywords used in the search of stewards' reports included "dislodge", "dislodged", "dislodging", "displace", "displaced", "displacing", "fall", "fell", "threw", "injury", "injured", "tumble", "harmless", "medical", "ambulance", "lost rider", "lost its rider", "bolt", "took charge", "rear" and "buck".

Once a fall incident was identified, details were recorded of the location (**Table 2-1**), outcome of fall (**Table 2-2**), cause of fall (**Table 2-3**), jockey and horse involved, and adjournment of any inquiry into a race incident.

Table 2-1: Record of location of the fall.

Field	Value	Text
IncidentLocation	1	Mounting Yard
IncidentLocation	2	PreRace WarmUp
IncidentLocation	3	Barriers
IncidentLocation	4	During Race
IncidentLocation	5	At Jump
IncidentLocation	6	Post Race
IncidentLocation	7	On Jump Out

Table 2-2: Record of outcome of the fall.

Field	Value	Text
Severity	1	Transported to Hospital
Severity	2	Declared Fit to Ride
Severity	3	Declared Unfit to Ride
Severity	4	Harmless Fall
Severity	5	Check Entry
Severity	6	Unknown
Severity	7	Took Place in Field

I was unable to obtain approximately 45% of stewards' reports from race meetings held between 1 August 2000 and 31 July 2002. This was primarily due to difficulty in locating archived reports, which in some cases was because of changes in administration of PRAs. Consequently, these racing years (2000-01 and 2001-02) were omitted from the analysis. For the period 1 August 2002 to 31 July 2006, ninety-three percent of stewards' reports were obtained. Later, these data were augmented with data from 1 August 2006 to 31 July 2009, of which ninety-eight percent of stewards' reports were obtained.

Summary information on stewards' reports that were not obtained is described in **Table 2-4**). The majority of missing reports not included in the analyses were from the earlier race seasons. A proportionally large number of the reports not obtained were from the Northern Territory, Victoria and New South Wales. About five percent of reports on flat races and six percent of reports on jumps races were not obtained. The reports not obtained had lower values for prize money and numbers of starters per race, reflecting the larger proportion of reports not obtained from country and amateur/picnic races.

Table 2-3: Record of cause of the fall.

Field	Value	Text
Cause	1	Bucked
Cause	2	Clipped Heels
Cause	3	Reared
Cause	4	Stumbled/Blundered
Cause	5	Dislodged
Cause	6	Unknown
Cause	7	Equipment Failure
Cause	8	Fractious
Cause	9	Horse Fell (Unknown)
Cause	10	Shifted Ground Abruptly
Cause	11	Jumped Crossing
Cause	12	Struck/Jumped Rail
Cause	13	Baulked/Shied
Cause	14	Careless Riding
Cause	15	Broke Down/Bled/Cardiac Arrest
Cause	16	Hampered by Fallen Horse/Rider
Cause	17	Bolted
Cause	18	Unbalanced/Lost Stirrup
Cause	19	Threw Self to Ground
Cause	20	Horse Fell (Clipped Heels)
Cause	21	Horse Fell (Stumbled/Blundered)
Cause	22	Horse Fell (Brought Down)
Cause	23	Horse Fell (Careless Riding)
Cause	24	Horse Fell (Broke Down/Bled/Cardiac Arrest)

Race field data

Racing Information Services Australia (RISA), the official repository for all thoroughbred race results across Australia, provided race field data for the race seasons 2002/03 through 2005/06, and later for race seasons 2006/07 through 2008/09. The data were provided in an Excel spread sheet. The fields included race code, number of starters in the race, race course name, date of race, race number, race type, race class, race distance in metres, track rating, penetrometer reading, weather conditions, prize money at stake, jockey code,

jockey surname, jockey preferred name, jockey given names, jockey sex, jockey licence status (apprentice, full licence), apprenticeship expiry date, horse name, finishing position, trainer surname, trainer preferred name, horse age and horse sex. In the subset of data covering 1 August 2006 to 31 July 2009, additional information was provided. The additional fields were weight carried by the horse, barrier position, handicap rating of the horse, betting starting price, jockey date of birth, total number of rides by jockey and total number of starts by horse.

Table 2-4: Comparison of race characteristics from stewards' reports obtained and not obtained

Variable		**Reports Obtained**		**Reports Not Obtained**	
		No.	**%**	**No.**	**%**
Season	2002/03	18,501	89.4%	2,201	10.6%
	2003/04	18,706	93.2%	1,366	6.8%
	2004/05	18,699	93.6%	1,269	6.4%
	2005/06	19,526	97.8%	437	2.2%
	2006/07	19,037	97.4%	508	2.6%
	2007/08	16,944	98.4%	267	1.6%
	2008/09	19,354	99.6%	87	0.4%
State	NSW	35,204	94.0%	2,259	6.0%
	VIC	29,337	91.7%	2,641	8.3%
	QLD	33,148	98.6%	473	1.4%
	SA	10,015	99.2%	77	0.8%
	WA	15,311	99.1%	146	0.9%
	TAS	4,272	99.5%	22	0.5%
	NT	2,419	82.7%	505	17.3%
	ACT	1,061	99.2%	9	0.8%
Race type	Flat	129,796	95.5%	6,072	4.5%
	Jumps	971	94.2%	60	5.8%
Race distance (metres)		1,358.67 (357.77)		1,349.48 (363.91)	
Prize money ($)		18,691.87 (70,523.87)		11,142.32 (32,249.30)	
Starters in race		9.95 (2.82)		8.90 (2.95)	
Total races		**130,767**		**6,135**	

Note: The means for race distance, prize money and starters are reported. Numbers in parentheses are standard deviations.

These data were imported into an Access database containing the stewards' reports and the incident falls data extracted from them. Merging of the data was achieved by one-to-one matching on race date, racecourse, race number, jockey name and horse name. The dataset was checked and cleaned by examining the distribution of the data for each variable using box-and-whiskers plots to identify outliers, by cross-validating related fields for consistency (eg. track-rating and penetrometers readings), by searching string variables for incorrect spelling and invalid characters, and by searching for duplicate and missing fields. Where possible, missing data were cross-checked against external race result sources such as the TOTE, TAB and CRIS (Western Australia's Customer Racing Information Service) online databases.

2.3 Database design

The resulting database – containing the stewards' reports, the incident data extracted from the stewards' reports and the race field data – is henceforth referred to as the "Menzies Research Institute (MRI): Jockeys Falls Database".

A requirements analysis was conducted with help from Mr. Tim Albion, who is an expert in database design, systems development and information technology. This involved determining the relationships and dependencies between the different data elements and producing a logical structure for the database on the basis of these relationships. **Figure 2-1** shows the relationship structure of the database. It was decided that Access would be an appropriate database software solution due to its ease of use and its ability to import and export data in many formats and to create tables, queries, forms and reports. The front of the database (**Figure 2-2**), import face for stewards' reports (**Figure 2-3**), example of an imported stewards' report (**Figure 2-4**), examples of race meeting (**Figure 2-5**) and race (**Figure 2-6**) details, an example of a recording of a jockey incident (**Figure 2-7**) and an extract of the incident information (**Figure 2-8**) are shown in screen shots that follow.

Figure 2-1: Relationship structure of the MRI: Jockey Falls Database

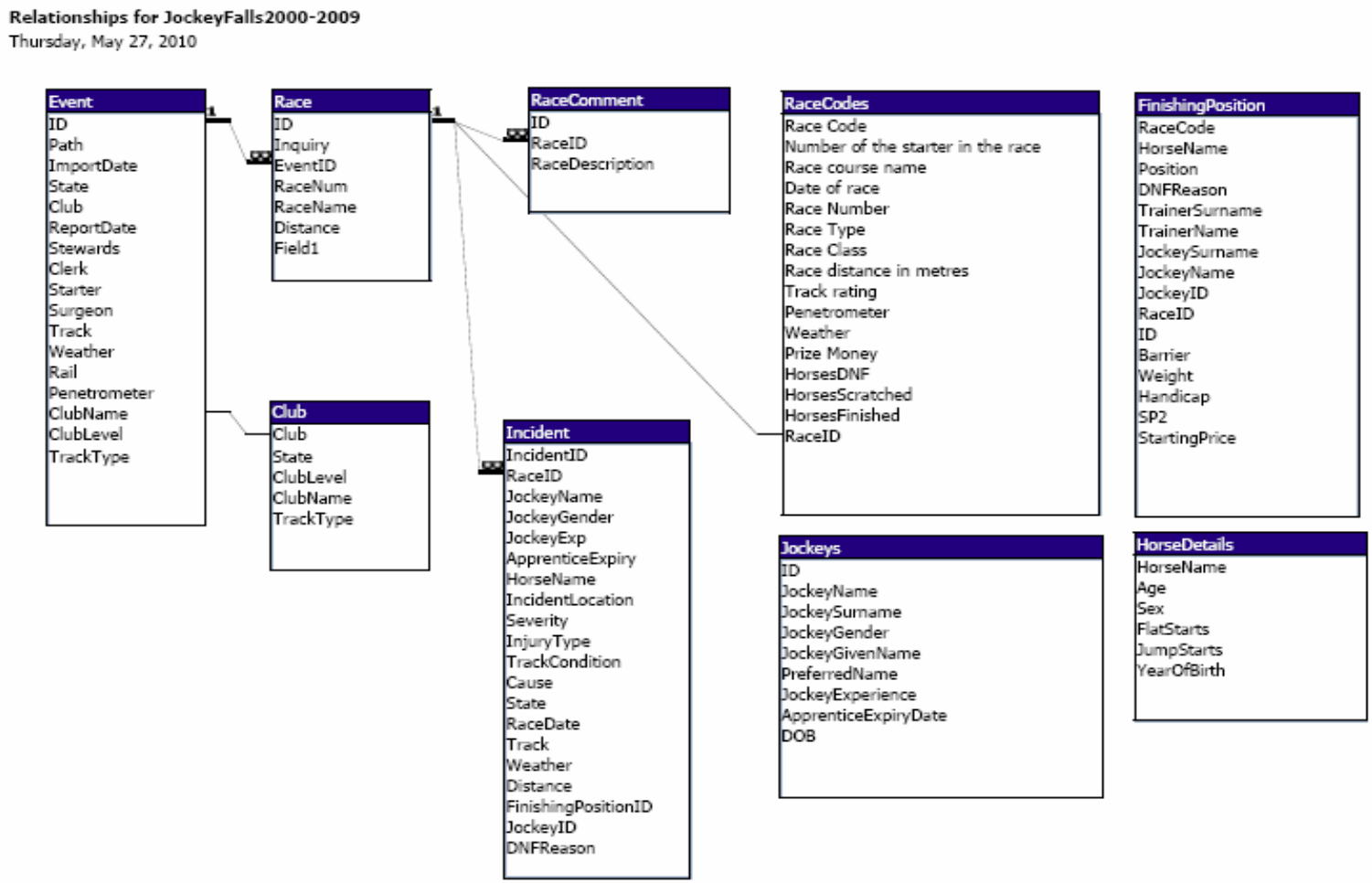


Figure 2-2: Front of database

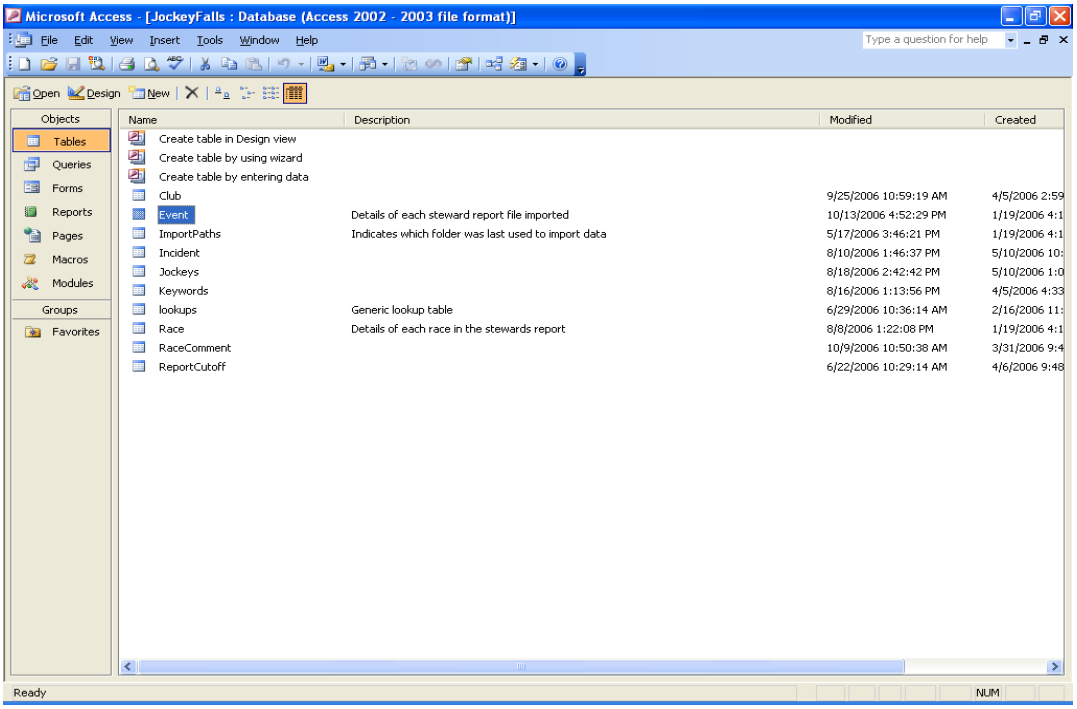


Figure 2-3: Import face for stewards' reports

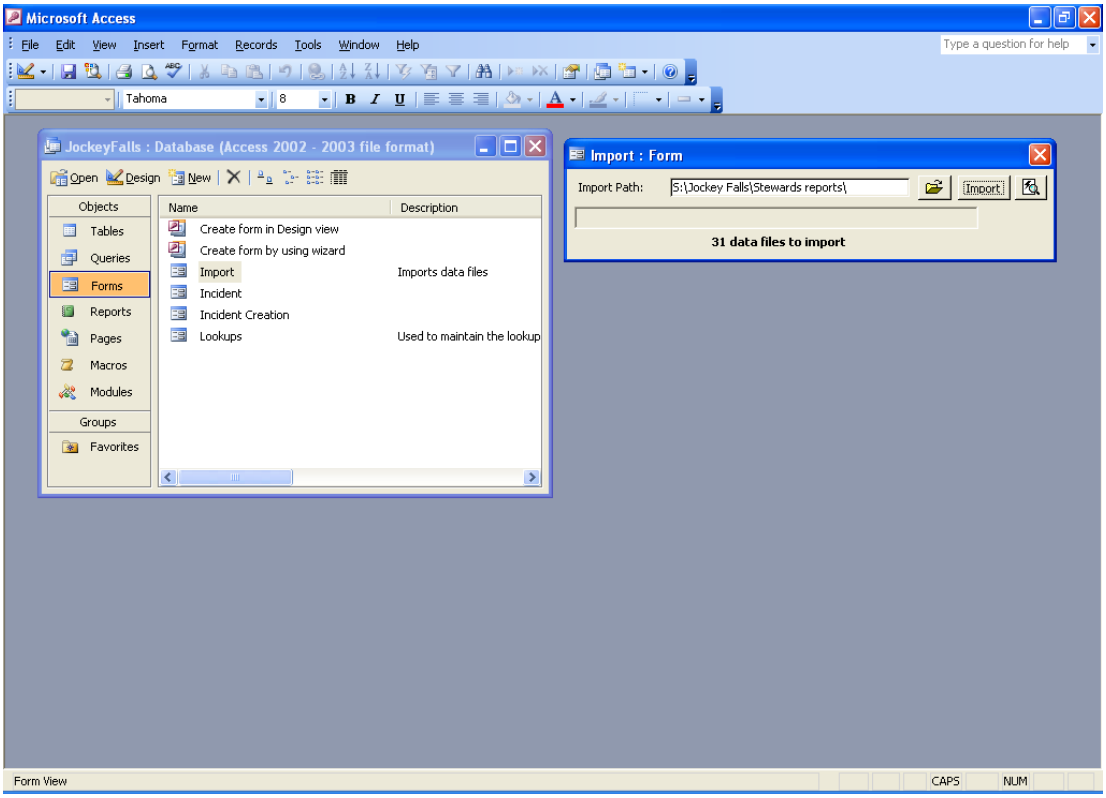


Figure 2-4: Example of imported stewards' report

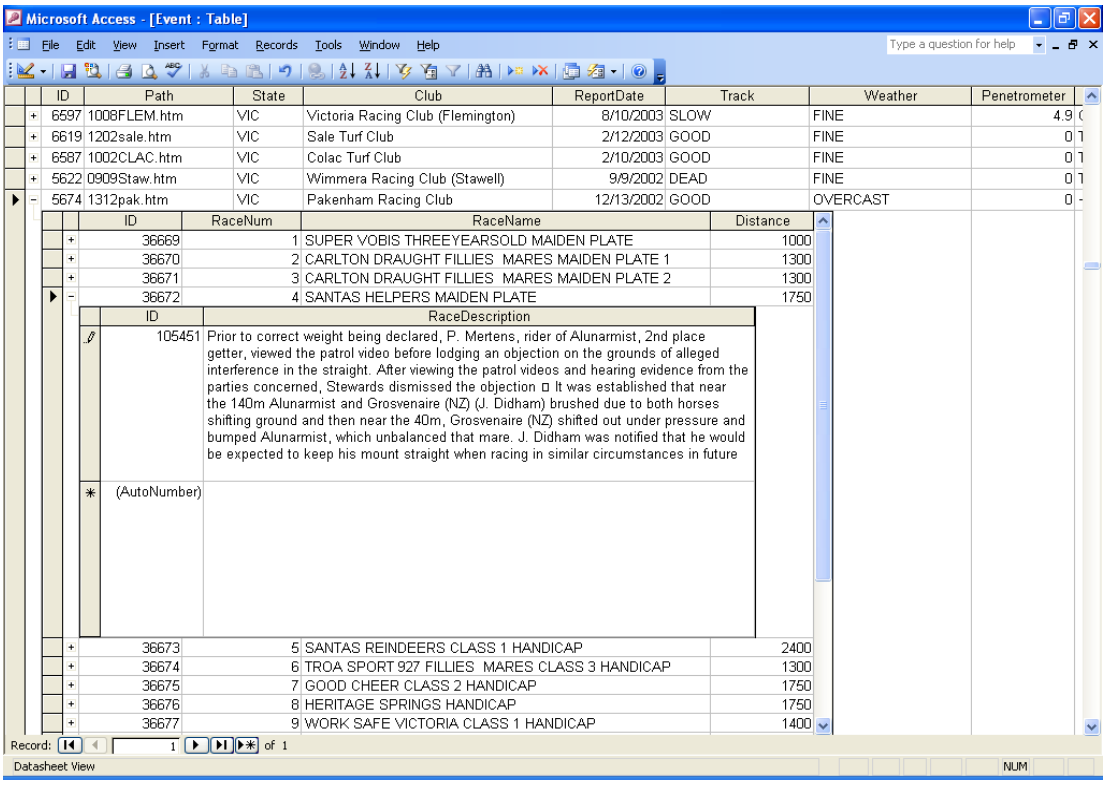


Figure 2-5: Race meeting details

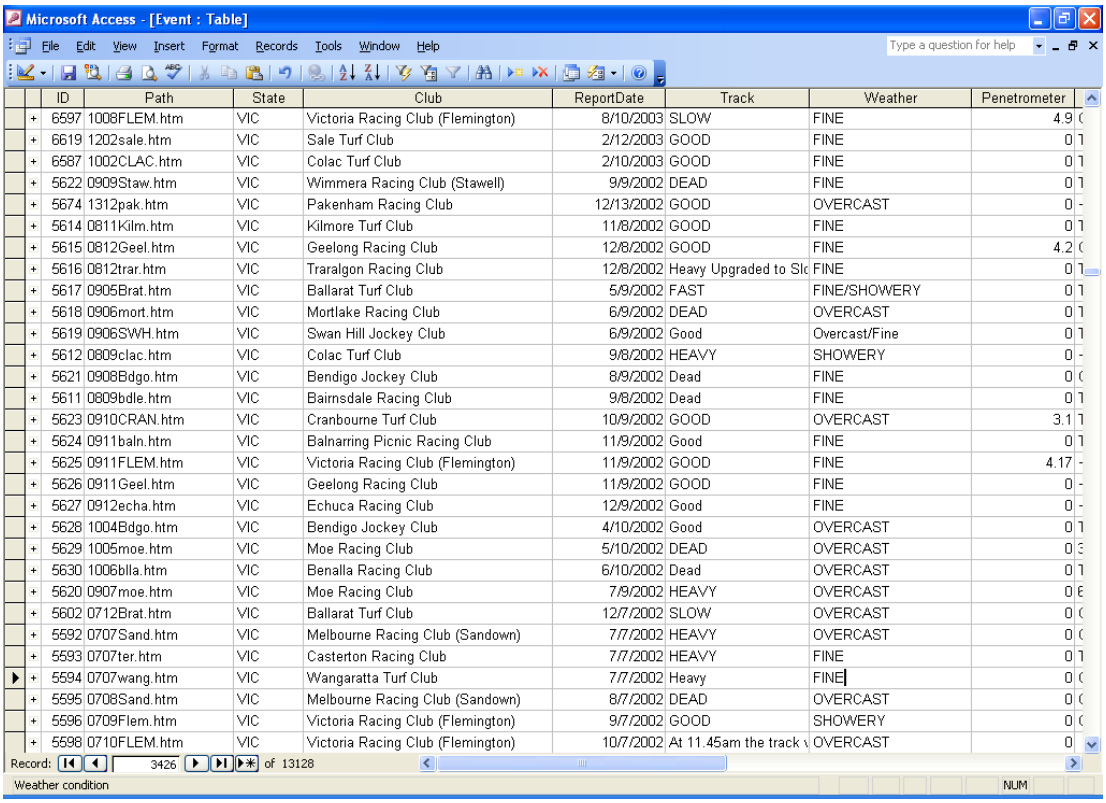


Figure 2-6: Race details

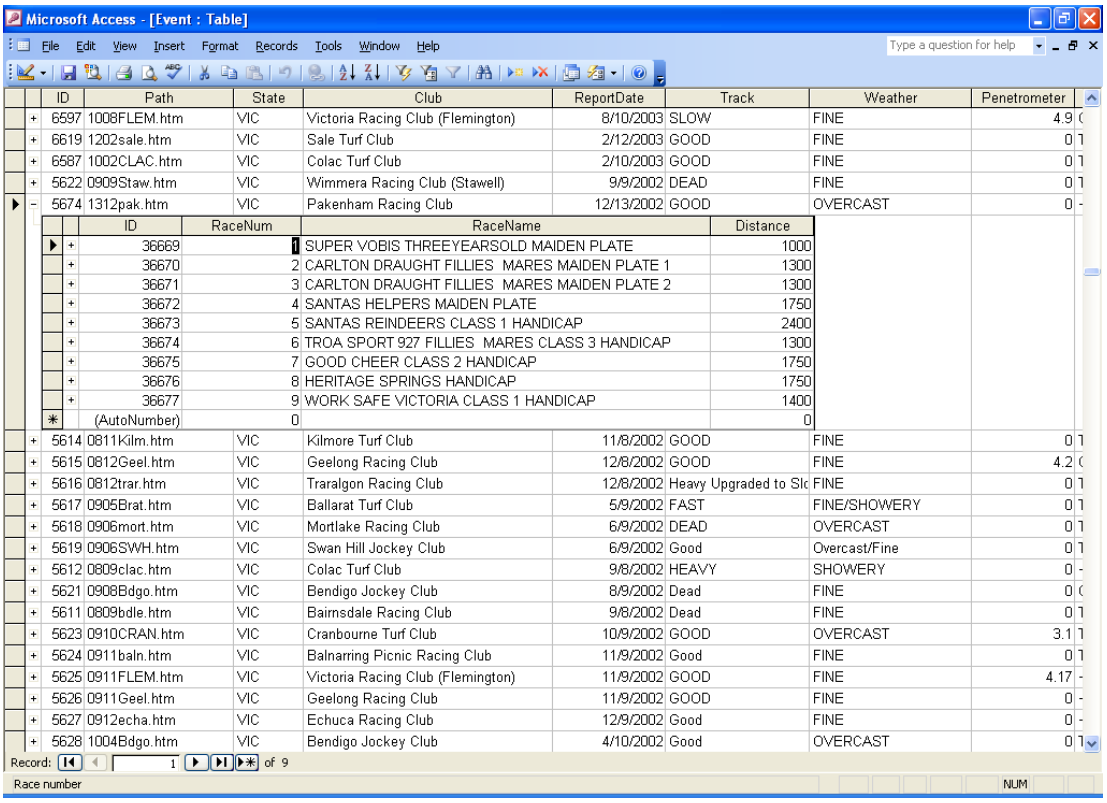


Figure 2-7: Recording of incidents

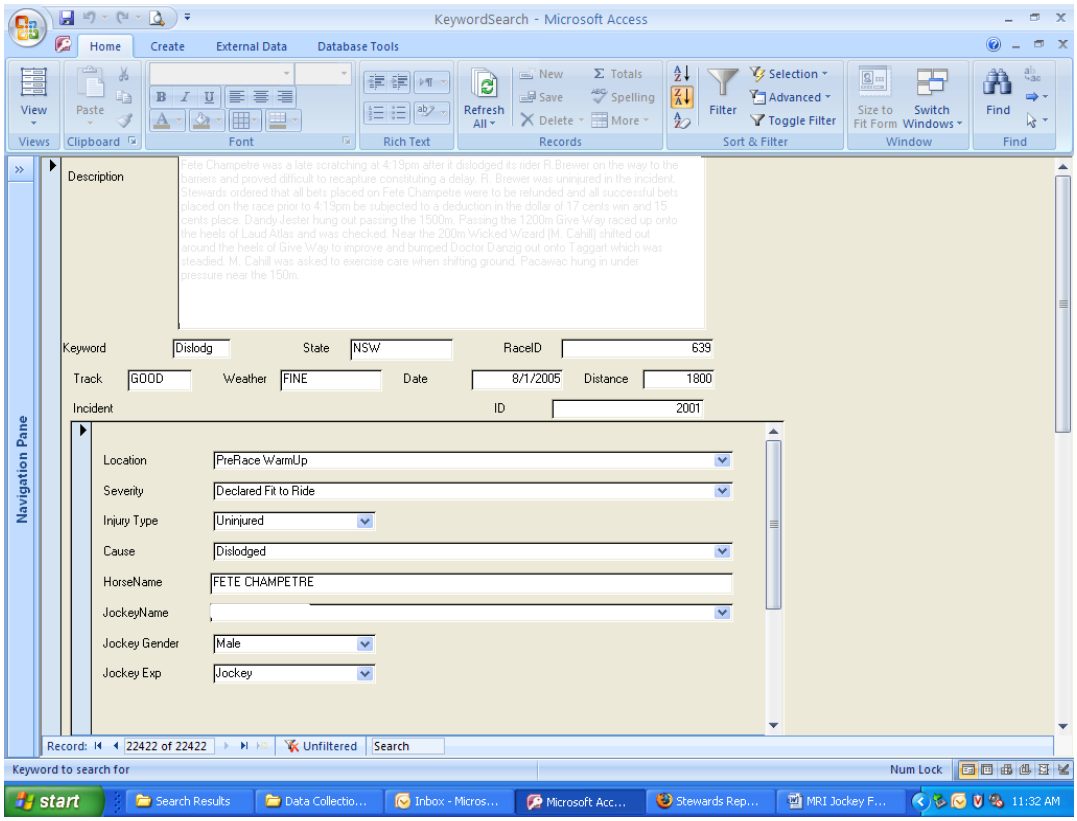
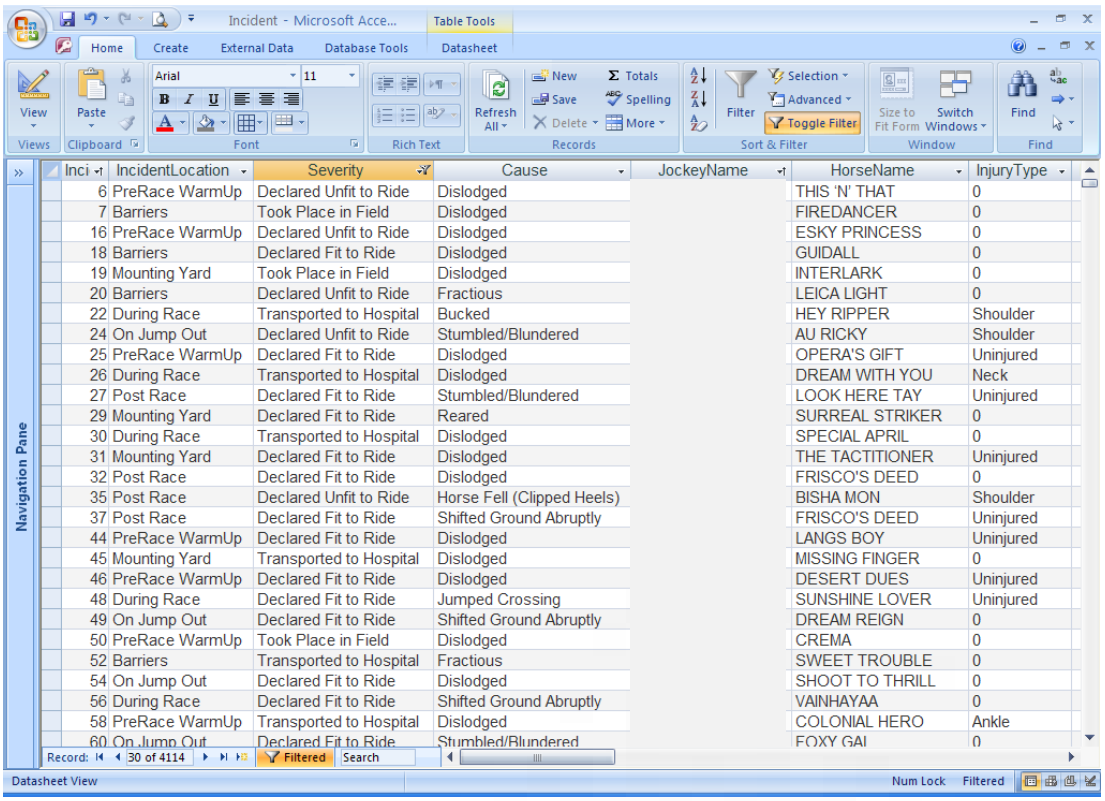


Figure 2-8: Extract of jockey incidents



Inci	IncidentLocation	Severity	Cause	JockeyName	HorseName	InjuryType
6	PreRace WarmUp	Declared Unfit to Ride	Dislodged		THIS 'N' THAT	0
7	Barriers	Took Place in Field	Dislodged		FIREDANCER	0
16	PreRace WarmUp	Declared Unfit to Ride	Dislodged		ESKY PRINCESS	0
18	Barriers	Declared Fit to Ride	Dislodged		GUIDALL	0
19	Mounting Yard	Took Place in Field	Dislodged		INTERLARK	0
20	Barriers	Declared Unfit to Ride	Fractious		LEICA LIGHT	0
22	During Race	Transported to Hospital	Bucked		HEY RIPPER	Shoulder
24	On Jump Out	Declared Unfit to Ride	Stumbled/Blundered		AU RICKY	Shoulder
25	PreRace WarmUp	Declared Fit to Ride	Dislodged		OPERA'S GIFT	Uninjured
26	During Race	Transported to Hospital	Dislodged		DREAM WITH YOU	Neck
27	Post Race	Declared Fit to Ride	Stumbled/Blundered		LOOK HERE TAY	Uninjured
29	Mounting Yard	Declared Fit to Ride	Reared		SURREAL STRIKER	0
30	During Race	Transported to Hospital	Dislodged		SPECIAL APRIL	0
31	Mounting Yard	Declared Fit to Ride	Dislodged		THE TACTITIONER	Uninjured
32	Post Race	Declared Fit to Ride	Dislodged		FRISCO'S DEED	0
35	Post Race	Declared Unfit to Ride	Horse Fell (Clipped Heels)		BISHA MON	Shoulder
37	Post Race	Declared Fit to Ride	Shifted Ground Abruptly		FRISCO'S DEED	Uninjured
44	PreRace WarmUp	Declared Fit to Ride	Dislodged		LANGS BOY	Uninjured
45	Mounting Yard	Transported to Hospital	Dislodged		MISSING FINGER	0
46	PreRace WarmUp	Declared Fit to Ride	Dislodged		DESERT DUES	Uninjured
48	During Race	Declared Fit to Ride	Jumped Crossing		SUNSHINE LOVER	Uninjured
49	On Jump Out	Declared Fit to Ride	Shifted Ground Abruptly		DREAM REIGN	0
50	PreRace WarmUp	Took Place in Field	Dislodged		CREMA	0
52	Barriers	Transported to Hospital	Fractious		SWEET TROUBLE	0
54	On Jump Out	Declared Fit to Ride	Dislodged		SHOOT TO THRILL	0
56	During Race	Declared Fit to Ride	Shifted Ground Abruptly		VAINHAYAA	0
58	PreRace WarmUp	Transported to Hospital	Dislodged		COLONIAL HERO	Ankle
60	On Jump Out	Declared Fit to Ride	Stumbled/Blundered		FOXY GAI	0

2.4 Data analysis

Definitions

A fall was defined as a rider being dislodged from a horse, regardless of the outcome, and an injury was considered to have occurred if the jockey was declared unfit to ride or was transported to hospital after a fall. This definition does not include minor injuries that did not preclude the jockey from riding later in the meeting.

Study factors

In flat racing analyses, race grade was categorised as maiden (horses having not won a race), class (horses classed from A-D in amateur racing or 1-6 in professional racing) and open and restricted conditions (horses racing in open graded races or races with restricted conditions). Jockeys were classified by licence (professional or amateur) and by experience (apprentice or full licence). Amateur jockeys do not receive a fee or reward for riding, and professional jockeys are paid a riding fee and receive a percentage of the prize money at stake. Additionally, amateur riders are only licensed to ride at picnic race meetings. Apprentice jockeys typically undergo a 4-year apprenticeship before they can obtain their full licence. Previous race rides at a race meeting were divided into the categories of 0 rides, 1 to 2 rides and 3 or more rides. The Australian and New Zealand

classifications of race distance – sprint (<1301m), middle (1301-1800m), intermediate (1801-2199m), long (2200-2700m) and extended (>2701m) – was used but with middle and intermediate categories combined ('middle') and long and extended categories combined ('staying'). Each level of track rating was based on penetrometer readings of water retention, with heavy indicating the wettest and fast indicating the driest ends of the scale. Club level was divided into metropolitan/provincial race clubs, country clubs and picnic clubs (where non-professional races are held). Field size refers to the number of starters in a race, and was divided into the categories of less than 8 starters, 8-12 starters, and over 12 starters.

In jumps racing, the covariates for field size, track rating and penetrometer reading are the same as for flat racing. To analyse factors associated with falls in two significantly different types of jumps racing, hurdle and steeplechase racing, the analyses were stratified by jumps race type. Typically, hurdle races are shorter in distance than steeplechase races. Hurdles are one metre in height and are used in hurdle races only. Steeplechase fences are not less than 1.15 metres in height and are used in steeplechase races only. Different types of jumps were used throughout the study period. New modular fences were rolled out during the study period, with 'Mark I' hurdles introduced from 2003 onwards, 'Mark II' hurdles and steeples from 2004 onwards, and 'Mark III' hurdles and steeples from 2005 onwards. Specific dates for introduction of the fences at each racecourse were obtained from a report by researchers at Flinders University [1]. Jumps jockeys were classified by cross-country licence (Licence A or Licence B). Jockeys holding a Licence A may ride in all jumping races conducted by a registered race club, whereas jockeys holding a Licence B may ride in jumping races at country race meetings only. Previous race rides at a race meeting was divided into the categories of 0 rides, 1 ride, and 2 or more rides. Race grade was divided into the three categories of maiden (horses having not won a race), restricted conditions (horses racing in races with restricted conditions) and open (horses racing in open graded races). The number of previous jump starts by the horse was divided into the categories of less than 5 starts, 5-9 starts, and 10 or more starts. Club level was divided into races conducted by metropolitan, provincial (clubs surrounding the metropolitan area, but not classified as country) and country race clubs. Race distances for hurdle races were classified as <3000m (shortest), 3000 to 3199m (intermediate) and ≥3200 (longest). For steeplechase races, race distances were classified as <3500 (shortest), 3500 to 3999m (intermediate) and ≥4000m (longest).

For a subset of the data covering the last three racing seasons (1 August 2006 to 31 July 2009), RISA provided information on weight carried, handicap rating, starting price and barrier position. Weight carried was divided into less than 63kgs, 64 to 65.5kgs, 66 to 67.5kg and over 68kgs. This refers to the total burden, in kilograms, that the horse carried in the race and includes the weight of the jockey plus the saddle. Handicap rating refers to the rating the handicapper has allocated a horse based on past performances. It was divided into four categories – 110 or less, 111 to 120, 121 to 130, and over 130. The starting price is the total return per unit wagered for a win, and is one plus the odds prevailing in the official bookmakers on-course fixed-odds betting market at the time the race began. Starting price was grouped into less than $5.00, $5.00 to $9.99, $10.00 to $19.99, and $20.00 or greater. Barrier position is the barrier or starting gate the horse starts from in the race and was divided into barriers 1 and 2, 3 to 5, 6 to 8, and 9 or over.

Measures of event occurrence

I provide here a brief summary of measures of event occurrence as background to the decisions taken on how falls data were reported in this study. A summary of epidemiological definitions can be found in **Table 2-5**.

Prevalence is defined as the proportion of persons in a given population who at a specified point in time (point prevalence) or during a specified period (period prevalence) are experiencing an event or have experienced an irreversible event. It may be expressed as a prevalence "rate" per 100,000 population, for example, but strictly it is a proportion and not a rate. Incidence refers to the number of new events in a defined population occurring during a specified period of time. It may be expressed as an incidence rate per year of person-time at risk. The numerator is the number of new events during the period and the denominator is the total person-time at risk of members of the population at risk of experiencing the event during the period. Cumulative incidence is defined as the proportion of a group of people at risk of an event who experience the onset of an event during a specified time period at risk [2].

Table 2-5: Summary of epidemiological definitions

Term	Definition	Example
Prevalence	The proportion of persons in a population who are experiencing a health-related event at a specified point in time	1% of the population injured at specific point in time
Incidence	The number of health-related events occurring in a population during a specified period of time at risk	20 events per year
Incidence rate	The number of health-related events per unit or quantum of person-time at risk, occurring in a population during a specified period of time at risk	20 events per 1000 person-years
Cumulative incidence	The proportion of a population at risk who experience a health-related event during a specified period of time at risk	10% of the population experience the event during a 5-year period

I considered various indices of time at risk. The options included:

a) the time in minutes that the jockey is mounted on the horse for the race, aggregated over races in each race meeting, race meetings in each race season, and race seasons. The various components of this time are:
    i. prior to the race, in the mounting yard, pre-race warm up on the track, and whilst the horse is in the barriers;
    ii. during the race, which is recorded and published but was not supplied to me;
    iii. post-race, during the cooling down and return to the mounting yard for weigh-in.

None of this information was supplied by RISA, and hence it was not feasible to apply this index.

b) as an indicator of time at risk during the race, I had information on the length of races. By aggregating over jockeys in each race, races in each race meeting, race meetings in each race season and race seasons, it was possible to calculate falls per kilometre travelled:

$$\text{Incidence Rate} = \frac{\text{Number of falls during period}}{\text{Distance travelled in period (km)}}$$

A limitation of this approach is that the number of falls would have to be restricted to those that occurred during the race.

c) as an indicator of the number of occasions on which a jockey was at risk, I had information on the rides and starters in each race. By aggregating over jockeys in each race, races in each race meeting, race meetings in each race season, and race seasons it was possible to calculate falls per ride:

$$\text{Incidence Rate} = \frac{\text{Number of falls during period}}{\text{Number of rides during period}}$$

d) number of races or race meetings a jockey would be at risk. This information would have enabled calculations of falls per race:

$$\text{Incidence Rate} = \frac{\text{Number of falls during period}}{\text{Number of races during period}}$$

or per race meeting:

$$\text{Incidence Rate} = \frac{\text{Number of falls during period}}{\text{Number of race meetings during period}}$$

A limitation of these two indices is that all races and race meetings are not the same. Consequently, risk may be affected by the number of starters in the race in the case of risk per race, or the number of races ridden in, in the case of risk per race meeting.

e) as an indicator of time at risk, I had information on the race season and year. This information would have enabled calculation of falls per race season:

$$\text{Incidence Rate} = \frac{\text{Number of falls during period}}{\text{Number of race seasons}}$$

A limitation of this index is that it does not take into account the number of times a jockey actually rides during a race season.

Following appraisal of the limitations of each approach, I chose the number of rides as the most appropriate index of time at risk. In reports of international studies from Japan [3], Great Britain [4], Ireland [4] and France [5], incidence rates are presented in percentages:

$$\text{Incidence Rate} = \frac{\text{Number of falls during period}}{\text{Number of rides during period}} \times 100$$

This is identical to falls per 100 rides. Thus an advantage of choosing the number of rides index of time at risk is that it allowed the results of this study to be reported in essentially the same units as previous studies.

For the purposes of this study, an injury was defined as the jockey being declared unfit to ride or transported to hospital following a fall. Injury incidence rates were therefore defined as:

$$\text{Injury Incidence Rate} = \frac{\text{Number of jockeys transported to hospital or declared unfit to ride during period}}{\text{Number of rides during period}} \times 100$$

2.5 Statistical power

Analysis of falls in flat racing

For these analyses, the data will consist of information on 3,101 falls in 743,445 rides for the period 2002/03 to 2005/06. The minimum incidence rate ratios able to be detected with 80% power (α=0.05) are shown in **Table 2-6** for a range of exposure proportions. The calculations are based on a formula for the standard error of the incidence rate ratio provided by Rothman [9].

Table 2-6: IRR's able to be detected with 80% power (α=0.05)

Exposure proportion	Minimum IRR detected
0.10	1.18
0.20	1.13
0.30	1.12
0.40	1.11
0.50	1.11

This study will have adequate power to detect incidence rate ratios in the range 1.1 to 1.2, which are much less than those observed in previous studies of horse falls. No previous study has examined risk factors for falls in flat racing. Pinchbeck *et al.* [10] reported odds ratios for horse falls in hurdle racing in the range of 3.16 (falls at the first fence) to 8.88 (races run at speeds greater than 3.9 furlongs per minute).

Analysis of falls in jumps racing

For these analyses, the data will consist of information on 259 falls in 4,922 rides (period 2002/03 to 2005/06) or 463 falls in 8,523 rides (period 2002/03 to 2008/09). As can be seen in **Table 2-7**, boosting the sample size by adding an additional three years of data has reduced the minimum excess risk detected by between 27% and 30%. The incidence rate ratios detected are within the range of values observed by Pinchbeck *et al.* [10, 11].

Table 2-7: IRR's able to be detected with 80% power (α=0.05)

Exposure proportion	Minimum IRR detected	
	2002/03 to 2005/06	2002/03 to 2008/09
0.10	1.73	1.51
0.20	1.52	1.37
0.30	1.45	1.32
0.40	1.42	1.30
0.50	1.41	1.30

2.6 Poisson regression

Analyses of incident data in **Chapters 3** to **5** and in **Chapter 7** were conducted using Poisson regression. The Poisson distribution can be employed to describe the number of occurrences of an event in a period of time (incidence). This method makes it possible to model the dependence of incidence on multiple covariates for study factors, and by including person-time (number of rides) as an offset, incidence rates can be modelled [6].

Following Dobson [7], suppose that a sample of n jockeys is observed and the number of falls observed in a period of time for each jockey is recorded. Let $Y_1, Y_2, \ldots, Y_n$ denote independent random variables with Y_i denoting the number of falls by the i^{th} jockey.

Denote the observed data by $y_1, y_2, \ldots, y_n$. The expected (mean) value of Y_i can be written as:

$$E(Y_i) = \mu_i = n_i\theta_i$$

where μ_i denotes the mean value, n_i is a parameter that indexes time at risk of a fall, and in this study represents the number of rides that the jockey has had, and θ_i denotes risk of falling in each ride and is a function of K covariates $X_{i1}, X_{i2}, \ldots X_{iK}$:

$$\theta_i = \theta(X_{i1}, X_{i2}, \ldots X_{iK})$$

Assume that the fall counts Y_i follow the Poisson distribution:

$$f(Y_i) = \frac{\mu_i^{Y_i} e^{-\mu_i}}{Y!}, Y_i = 0, 1, 2, \ldots$$

For a particular value of the mean fall rate of the i^{th} jockey, μ_i, this function can be used to estimate the probability that the jockey will have exactly zero falls ($Y_i = 0$) during the period, the probability that the jockey will have exactly one fall ($Y_i = 1$) during the period, the probability that the jockey will have exactly two falls ($Y_i = 2$) during the period, and so on. It can be shown that the mean of the distribution is $E(Y_i) = \mu_i$ and its variance is $Var(Y_i) = \mu_i$ also.

In the Poisson regression model, the dependence of the fall-per-ride rate θ_i on the covariates is specified as:

$$\theta_i = \exp(\beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_K X_{iK}) = e^{\beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_K X_{iK}}$$

so that:

$$E(Y_i) = \mu_i = n_i e^{\beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_K X_{iK}}$$

Taking logarithms, the Poisson regression model can be written in log-linear form as:

$$\ln(\mu_i) = \ln(n_i) + \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_K X_{iK}$$

This equation differs from the specification of a normal-errors log linear model because of (i) the requirement that the regression errors follow the Poisson distribution (rather than the Normal distribution as in the case of the normal errors model), and (ii) the inclusion of the term $\ln(n_i)$. This term, the logarithm of the number of rides, is referred to as an offset. It is a known constant that does not have a coefficient to be estimated. It is readily incorporated into the estimation procedure, which involves specifying the likelihood of the data under the Poisson model and using an iterative technique to find the set of estimates $\hat{\beta}_0, \hat{\beta}_1, \hat{\beta}_2, .., \hat{\beta}_K$ that produce the maximum value of the likelihood for the observed values $y_i, x_{i1}, x_{i2}, .., x_{iK}$ of the data for $i = 1, 2, .., n$. Note, using a property of logarithms, that:

$$\ln(\mu_i) - \ln(n_i) = \ln\left(\frac{\mu_i}{n_i}\right) = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_K X_{iK}$$

so that, in effect, it is the rate of falls $\left(\frac{\mu_i}{n_i}\right)$ that is being modeled.

In the terminology introduced by McCullagh and Nelder [8], the Poisson regression model is a member of the exponential family of generalized linear models with a Poisson-distributed outcome variable Y_i for $i = 1, 2, .., n$, a linear predictor $\beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_K X_{iK}$, and a logarithmic link between the mean μ_i of the outcome variable and the linear predictor.

For a binary (0/1) covariate X_j with values $X_j = 0$ denoting that the factor is absent and $X_j = 1$ denoting that the factor is present, the effect of the presence versus absence of the factor, on the estimated rate $\hat{\mu}_i$, is measured as the multiplicative factor:

$$\frac{E(Y_i | x_{ij} = 1)}{E(Y_i | x_{ij} = 0)} = e^{\widehat{\beta}_j}$$

provided all other factors are held constant. Similarly, for a continuous explanatory factor X_k, a one-unit increase will result in a multiplicative effect $e^{\widehat{\beta}_k}$ on the estimated rate $\hat{\mu}_i$. Therefore the parameter estimates can be interpreted on the exponential scale as ratios of rates (or incidence rate ratios).

For multivariable analyses in **Chapter 4** and **Chapter 5**, the significant predictors from univariable analyses were entered in a single model. All variables, regardless of p-value, were tested for interactions with other variables, and were re-entered into the model as main-effects to assess for confounding.

Data manipulation to speed fitting of the model

When analysing the data in STATA 10.0, the Poisson model took considerable time to iterate to convergence (upwards of 20-30 minutes for each univariable analysis, and longer still for each multivariable analysis). This was due to the large size dataset: for the analysis of data on flat racing from 2002/03 to 2005/06, there were almost 750,000 records and, when augmented with data for 2006/07 to 2008/09, this increased to almost 1.3 million records. To speed the fitting of the model, a pragmatic solution was to collapse the dataset by replacing multiple observations for each jockey – one for each ride with an indicator variable to identify whether or not a fall had occurred during that ride – with a single observation with two summary statistics – the total number of rides, and the total number

of falls – for all those that shared the same covariate values for that jockey. This made it possible to replace thousands of observations on the same jockey with usually less than 50 depending upon the covariates in each analysis and the number of different covariate patterns for each jockey. Burton *et al.* [12] argue that summarising the data for each individual using a summary statistic is a valid approach to resolving the issue of repeated measurements on the same individual. This approach, which is referred to as data resolution, is safe and can be recommended when it is reasonable to address a research question in such a manner. Furthermore, although it is not fully efficient because the full information content of the data is not extracted, the information lost on factors such as time between falls was not directly relevant to these analyses. Jockey experience and career stage are the focus of the time-to-event analyses in **Chapter 6**.

This had several implications:

1) there no longer was a problem with the data having more "zeros" in the field for falls (ie. rides without falls) than would be expected if the data followed a Poisson distribution. For example, there were 1,288,031 "zeros" (non-falls) and only 5,314 "non-zeros" (falls) in the full dataset of 1,293,345 records. No Poisson distribution, whatever its mean, could provide a good fit to those data and it would have been necessary to investigate the use of zero-inflated Poisson models and the zero-inflated negative binomial regression model [6]. Collapsing the data avoided this;
2) for most analyses, there was no longer a problem with under-dispersion of the data (variance less than the mean) relative to the Poisson distribution for which the mean $E(Y_i) = \mu_i$ and variance $Var(Y_i)$ are identical [6]. Under- or over-dispersion can be detected using the deviance that is defined as:

$$D = 2\sum_{i=1}^{n}\left[y_i \ln\left(\frac{y_i}{\hat{\mu}_i}\right) - (y_i - \hat{\mu}_i)\right]$$

where

$$\hat{\mu}_i = n_i e^{\beta_0+\beta_1 X_{i1}+\beta_2 X_{i2}+\ldots+\beta_K X_{iK}}$$

is the predicted number of falls. The deviance divided by degrees of freedom should be approximately equal to one if the model is correctly specified. Values greater than one indicate over-dispersion (variance greater than the mean), and values less than one indicate under-dispersion (variance less than the mean) [6 ,13]. The Pearson chi-squared statistic:

$$X^2 = \sum_{i=1}^{n} \frac{(y_i - \hat{\mu}_i)^2}{\hat{\mu}_i}$$

divided by its degrees of freedom should be equal to one if the model is correctly specified, and this could be used as an alternative method of detecting under- or over-dispersion, but these statistics are asymptotically equal [7] and effectively equivalent in our large dataset. In the flat racing model reported in **Chapter 4**, collapsing the dataset over covariate patterns for each jockey increased the deviance statistic relative to its degrees of freedom such that the ratio of deviance to its degrees of freedom fell between 1 and 2. Thus there was slight over-dispersion in models fitted to the collapsed data but, as the deviance did not exceed 2, there was no cause for concern [6]. In the jumps racing model (**Chapter 5**), the data were not collapsed because there were far fewer observations (8,523 rides and 463 falls) and under-dispersion remained. This was handled by re-scaling the covariance matrix by multiplying it by the deviance ratio. This has the effect of reducing the estimated standard errors when the deviance is less than its degrees of freedom.

3) Even in the collapsed data for each jockey, there were multiple observations on the same jockey and it was necessary to adjust the standard errors to take account of clustering. This was done using Stata's robust option that implements the Huber-White sandwich estimator [14,15].

2.7 Cox proportional hazards regression

Time-to-event (survival analysis) methods are used in **Chapter 6** to investigate factors associated with falls. This method takes account of varying length of follow-up, which was necessary because some apprentice jockeys completed more than 2000 rides by the end of the period whilst others had just commenced their careers, and does so in a different manner to Poisson regression by using a censoring mechanism for incomplete observation of time-to-event. Time-to-event analysis seemed to be an appropriate analytical approach to answer the research questions posed in that chapter. It includes a class of semi-parametric models that are particularly suitable for regression analysis provided that a stringent modelling assumption is satisfied.

In time-to-event terminology, following Hosmer, Lemeshow and May [16], the hazard function represents the hazard rate (or failure rate) as a function of time and covariates.

For a jockey, the hazard rate is the probability of falling in an instant of time after time t conditional on not having fallen prior to time t. For the i^{th} jockey in a sample of n jockeys, the hazard of a fall can be written as a function of time t and K covariates:

$$h_i = h(t, X_{i1}, X_{i2}, .., X_{iK}) | y_1 = y_2 = \cdots y_{t-1} = 0$$

How this function is parameterised depends upon the class of time-to-event regression model used. The particular assumptions of the Cox proportional hazards model are that (i) the hazard function can be decomposed into a function of time (expressing how the hazard function varies with time-at-risk) and a separable function of covariates (expressing how the hazard function varies with the covariates):

$$h_i = h_0(t) r(X_{i1}, X_{i2}, .., X_{iK})$$

where $h_0(t)$ is a function of time that represents the baseline hazard when the values of all covariates are zero, and that (ii) the function of covariates has the simple exponential form:

$$r(X_{i1}, X_{i2}, .., X_{iK}) = e^{\beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_K X_{iK}}$$

where $\beta_1, \beta_2, .., \beta_K$ are coefficients to be estimated. Note that the linear predictor:

$$\beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_K X_{iK}$$

does not include a constant (there is no β_0). With these simplifications, the hazard function is:

$$h_i = h_0(t) e^{\beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_K X_{iK}}$$

For a binary (0/1) covariate X_j with value $X_j = 0$ denoting that the factor is absent and $X_j = 1$ denoting that the factor is present, the effect of the presence versus absence of the factor is measured as the hazard ratio (HR):

$$\widehat{HR} = e^{\widehat{\beta}_j}$$

Similarly, for a continuous explanatory factor X_k, a one-unit increase will result in a hazard ratio of $e^{\widehat{\beta}_k}$.

In the particular parameterization used, race rides were specified as an approximate index of time-at-risk. The unit of "time" in this analysis was each race ride, and the jockey was considered to have survived to the next point in "time" (the next ride) if he/she had not had a fall during the last race ride. This race ride index is approximate at best because it takes no account of the length of time the jockey is mounted on the horse and at risk of falling (the time-at-risk depends on the location of the starting barriers relative to the mounting yard, the distance of the race, the speed of the horses, and so forth). A property of the Cox proportional hazards model is that it is not necessary to explicitly specify the survival time function as is required in a fully parametric analysis. The purpose of the analysis in

Chapter 6 was to compare survival probabilities at different levels of the covariates, and particularly at different levels of jockey experience and career stage, and for this purpose the semi-parametric proportional hazards approach was adequate. To test whether our predictors satisfied the proportional hazards assumption Kaplan-Meier curves [17] were generated for categorical covariates and Schoenfeld residuals [18] were obtained for all covariates (both categorical and continuous) [19]. All covariates satisfied the proportional hazards assumption with the exception of the continuous variable for number of career rides. For this reason, as well as to demonstrate changes in hazard ratios across levels of jockey experience, the univariable results were stratified on the non-proportional covariate (number of career rides) to allow the baseline hazards to differ by category of jockey experience.

Two particular features of the analysis were that it had to take account of (i) recurrent events and (ii) time-varying covariates. The recurrent events in question were multiple falls, with 40.8% of jockeys having at least 2 falls during the study period and one jockey having as many as 30 falls. For this purpose, the gap-time modelling approach described by Prentice *et al.* [20] was employed. The model specification is conditional in that a subject (jockey) is assumed to not be at risk for a subsequent event (fall) until a prior fall has occurred, and follow-up time (number of rides between falls) is reset to zero after each fall occurs. This results in multiple periods of observation on the same jockey that are multiple records for analysis, and the lack of independence between multiple records for the same jockey (clustering on jockey) is taken into account by adjusting the standard errors calculated under the assumption of independence. The time-varying covariates were either discrete, or were handled in analysis as if they were discrete (by categorising scaled variables such as prize money and horse age). In survival analysis, the method of handling discrete time-varying covariates is to create a new record each time the covariate changes. This requires extensive data manipulation in general but, for this study, discretely time-varying covariates were handled automatically because each ride provided a new observation (and hence a new record for analysis with its own set of values for the covariates).

2.8 Postscript

This chapter has presented the methods for data collection, database design, and data analysis. The database is the first comprehensive collection of incident information on falls

and injuries to licensed jockeys at Australian thoroughbred race meetings. The reports in **Chapter 3-7** are based on analyses of the data it contains. In the next chapter, jockey fall, injury and fatality rates will be reported using the data from the 2002/03 to the 2005/06 racing seasons contained within the database.

2.9 References

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could be traced from their first ever race ride, and to investigate experience-related factors that may have contributed to the falls they had. This is a report of factors associated with falls by apprentice jockeys in Australia during the period 2002/03 to 2008/09.

6.3 Methods

Sources of data

Incident data on falls of licensed jockeys at race meetings throughout Australia were collated through a search of stewards' reports provided by the Principal Racing Authority (PRA) of each state or territory of Australia. Using these data, it was possible to investigate falls occurring from the time the jockey mounted the horse pre-race to the time of dismounting post-race. A fall was defined as a rider being dislodged from a horse, regardless of the outcome, and a significant injury was considered to have occurred if the jockey was declared unfit to ride or was transported to hospital after a fall. Racing Information Services Australia (RISA), the official repository for all thoroughbred race results across Australia, provided comprehensive data on every race conducted at race meetings run by a PRA from 1 August 2002 to 31 July 2009. These data were merged with the incident falls data by 1:1 matching on race date, race course, race number, jockey name and horse name. These data covered 96% of race rides by jockeys during the study period. Details of the methods used here have been reported previously [1].

Statistical analysis

Two sets of analyses were undertaken. The first focused exclusively on apprentice jockeys who commenced race riding during the study period (1 August 2002 to 31 July 2009). For these analyses, jockey experience was classified by the number of career rides in six categories: less than 50 rides, 50 to 249 rides, 250 to 499 rides, 500 to 999 rides, 1000 to 1999 rides, and 2000 rides or more. The second set of analyses focused on career stage to allow comparisons of these "early-career" jockeys (those who commenced their race riding career during the study period) with "mid-career" jockeys (those who were 30 years of age or younger on 1 August 2002 but had commenced their race riding career prior to the study period) and "late-career" jockeys (those who were older than 30 years of age and had commenced their race riding career prior to the study period).

Table 6-1 to **Table 6-4** and **Figure 6-1** present results for the "early-career" apprentice jockeys. The statistical significance of the difference across experience categories in **Table 6-2** for categorical variables was assessed using the Pearson's chi-square ($\chi 2$) test. For

continuous variables a quantile regression model was fitted to assess the trend in median values across experience categories. The p-value reported is the test of significance of the coefficient of a linear predictor with category mean scores (0-49 rides=24, 50-249 rides=142, 250-499 rides=367, 500-999 rides=722, 1000-1999 rides=1405, ≥ 2000 rides=2694). In **Figure 6-1**, the fall rate was expressed as the number of falls per 100 rides:

$$\text{Incidence (falls per 100 rides)} = \frac{\text{Number of falls during period}}{\text{Number of rides during period}} \times 100$$

A trend line was fitted to the data using Poisson regression. By using a logarithmic link to model the logarithm of the mean number of falls for each category of career rides and including the logarithm of the number of rides as the offset, the rate of falls was modelled as a log-linear function of the mid-points of the experience categories used in **Figure 6-1**.

Time-to-event (survival analysis) methods were used to investigate factors associated with falls. The Cox proportional hazards model was used to model the instantaneous probability (hazard) of falls as a function of time and covariates. In the particular parameterization used, race rides were specified as an approximate index of time-at-risk. The unit of "time" in this analysis was each race ride, and the jockey was considered to have survived to the next point in "time" (the next ride) if he/she had not had a fall during the last race ride. Two particular features of the analysis were that it had to take account of (i) recurrent events and (ii) time-varying covariates. The recurrent events in question were multiple falls, with 40.8% of jockeys having at least 2 falls during the study period and one jockey having as many as 30 falls. For this purpose, the gap-time modelling approach described by Prentice *et al.* [12] was employed. The model specification is conditional in that a subject (jockey) is assumed to not be at risk for a subsequent event (fall) until a prior fall has occurred, and follow-up time (number of rides between falls) is reset to zero after each fall occurs. This results in multiple periods of observation on the same jockey, and this clustering was taken into account by adjusting the standard errors calculated under the assumption of independence. The time-varying covariates were either discrete, or were handled in analysis as if they were discrete (by categorising scaled variables such as prize money and horse age). For this study, discretely time-varying covariates were handled automatically because each ride provided a new observation (and hence a new record for analysis with its own set of values for the covariates).

To test whether our predictors satisfied the proportional hazards assumption, Kaplan-Meier curves were generated for categorical covariates and Schoenfeld residuals were obtained for all covariates (both categorical and continuous) [13]. All covariates satisfied the proportional hazards assumption with the exception of the continuous variable for number of career rides. For this reason, as well as to demonstrate changes in hazard ratios across levels of jockey experience, the univariable results were stratified on the non-proportional covariate (number of career rides) to allow the baseline hazards to differ by category of jockey experience.

For study factors with multiple categories, binary (0/1) indicator variables for categories other than the reference category were included in the model. Tests for linear trend in the hazard ratios for ordered categorical variables were conducted by replacing the binary indicators with the single predictor for jockey experience and assessing the statistical significance of its coefficient. Interaction was assessed from tests of the coefficients of product terms formed from the linear predictor for jockey experience and each of the covariates. Effect modification was considered present if the test of the coefficient of the product term yielded a p-value less than 0.05. Hazard ratios with 95% confidence intervals (CI) have been presented.

Table 6-5 and **Table 6-6** present results for jockeys at the three career stages. Interaction in **Table 6-5** was assessed from the tests of the coefficients of product terms formed from the linear covariate for career-stage (1=early-career, 2=mid-career, 3=late-career) and each covariate.

All analyses were performed using Stata version 10.0 (StataCorp, College Station, Texas, USA).

6.4 Results

Table 6-1 provides summary data on apprentices who commenced their race riding career between 1 August 2002 and 31 July 2009. There were 303 injuries and 1,311 falls by jockeys, from 254,449 flat race rides in 95,164 flat races and 15,785 race meetings.

Table 6-2 presents data tracing the early career of jockeys who commenced flat race riding as apprentices during the study period. The data are stratified by category of jockey

experience based upon number of rides. Tests for independence for all categorical variables were statistically significant ($p<0.001$), as were tests for trend for all continuous variables ($p<0.001$). Jockeys with fewer career rides generally were younger in age, had been riding for a shorter amount of time, had a lower winning strike rate, had fewer rides per month, had fewer rides at a race meeting, rode horses that had had a greater number of previous race starts, rode horses that were older in age, rode in lower grade races, rode in races with less prize money at stake, rode at lower club levels, rode in races with fewer starters, rode in races over shorter distances, rode in races on drier tracks, rode in more races on dirt or sand tracks, and rode under sunnier weather conditions. Adjusted for number of rides per month, the association between track conditions and jockey experience was no longer statistically significant ($p=0.080$).

Figure 6-1 depicts fall incidence rates by number of career rides for jockeys who commenced their apprenticeship during the study period. The fall rate decreased in a log-linear fashion with the number of races that the apprentice jockeys had ridden in ($p< 0.001$).

Table 6-3 presents the number of falls, rides, rate of falls and hazard ratios for early career jockeys, stratified by category of number of career rides. There is a clearly discernable and statistically significant ($p<0.001$) inverse association between hazard of falls and apprentice jockey experience.

Table 6-4 presents hazard ratios stratified by category of number of career rides. In univariable analysis, significant predictors of falls were jockey age at commencement of career ($p=0.001$), previous rides this meeting ($p<0.001$), previous starts by the horse ($p<0.001$), horse age ($p<0.001$), race grade ($p<0.001$), prize money at stake ($p<0.001$), race distance ($p<0.001$), track rating ($p<0.001$) and fine (HR 0.81; 95% CI 0.70, 0.94; $p=0.005$) and overcast (HR 0.72; 95% CI 0.52, 1.00; $p=0.049$) weather conditions compared to sunny conditions. Three predictors differed significantly across category of number of career rides. The greater hazard ratio for jockeys with fewer career rides was more pronounced in lower grade races (interaction $p=0.046$), in races with less prize money at stake (interaction $p=0.009$) and in races shorter in distance (interaction $p=0.051$).

Table 6-1: Apprentices commencing their race riding career between 2002/03 to 2008/09 racing seasons.

	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09
Apprentice jockeys (N=514)	89	79	69	63	74	69	71
Number of rides (N+=254,449)	4,615	14,498	27,733	39,448	50,808	53,776	63,571

Figure 6-1: Fall incidence rates by number of career rides of jockeys who commenced their race riding career during the study period (p<0.001 for trend).

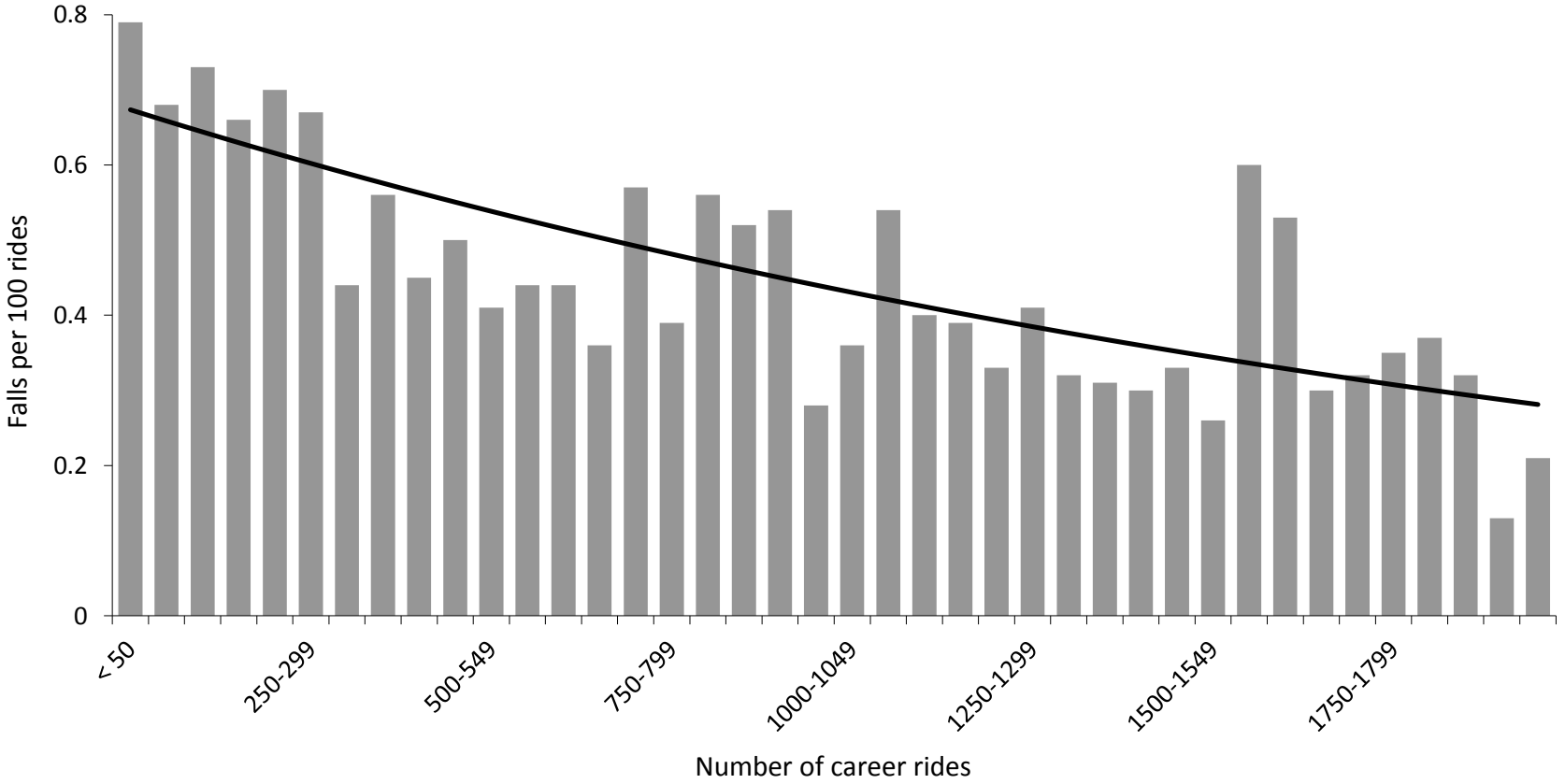

Table 6-2: Descriptors of the early career jockeys who commenced flat race riding during the study period.

	Category of experience (number of career rides)					
Study factor	**< 50 rides**	**50 – 249 rides**	**250 – 499 rides**	**500 – 999 rides**	**1000 – 1999 rides**	**≥ 2000 rides**
Sex of jockey						
% male jockeys	64.1%	64.8%	69.7%	69.8%	79.1%	78.6%
Jockey age						
Median (IQR)	18.84 (17.08, 22.05)	19.45 (17.51, 22.57)	19.87 (17.98, 23.26)	20.34 (18.43, 23.15)	20.92 (19.14, 22.70)	21.52 (19.94, 23.18)
Months riding						
Median (IQR)	3 (2, 5)	12 (9, 17)	24 (18, 31)	34 (26, 44)	44 (36, 52)	57 (49, 66)
Winning strike rate (%)						
Median (IQR)	5.26 (0, 10.87)	8.33 (5.73, 11.23)	8.95 (7.11, 11.25)	9.56 (8.17, 11.10)	9.70 (8.39, 11.08)	10.27 (8.60, 11.86)
Number of rides per month						
Median (IQR)	3 (6, 10)	12 (6, 19)	17 (9, 28)	23.5 (13, 39)	34 (21, 50)	46 (31, 62)
Number of rides at meeting						
Median (IQR)	2 (1, 3)	2 (1, 4)	3 (1, 4)	3 (2, 5)	3 (2, 5)	3 (2, 5)
Previous horse starts						
Median (IQR)	11 (5, 22)	13 (6, 23)	13 (5, 25)	13 (5, 25)	12 (5, 23)	9 (3, 18)
Horse age						
Median (IQR)	5.12 (4.24, 6.34)	5.04 (4.19, 6.16)	4.93 (4.07, 6.06)	4.87 (3.98, 5.97)	4.75 (3.85, 5.83)	4.49 (3.69, 5.51)
Horse gender						
Entire	2% (410)	2% (1,186)	2% (933)	3% (1,471)	3% (1,397)	4% (800)
Filly/mare	37% (7,588)	38% (21,432)	38% (17,889)	38% (21,777)	39% (20,256)	41% (8,348)
Gelding	61% (12,272)	60% (34,516)	61% (28,782)	60% (34,292)	58% (29,774)	55% (11,254)

Study factor	Category of experience (number of career rides)					
	< 50 rides	**50 – 249 rides**	**250 – 499 rides**	**500 – 999 rides**	**1000 – 1999 rides**	**≥ 2000 rides**
Notes: for continuous variables the median and interquartile range (IQR) are presented; for categorical variables the percentage rides (number of rides) are presented.						
Race grade						
Maiden	33% (6,636)	32% (18,543)	32% (15,045)	28% (16,372)	28% (14,163)	29% (5,969)
Class	52% (10,331)	54% (30,766)	54% (25,490)	53% (30,461)	50% (25,565)	44% (8,979)
Open/Restricted	15% (2,948)	14% (7,971)	15% (7,158)	19% (10,796)	23% (11,767)	27% (5,487)
Prize money (AU$)						
Median (IQR)	6,500 (4250, 9000)	7,500 (5250, 10000)	9,000 (6500, 11600)	10,000 (7700, 15000)	12,000 (9000, 24000)	15,000 (11000, 30000)
Club level						
Metropolitan	6% (1,125)	9% (4,915)	13% (6,302)	26% (15,002)	35% (17,900)	39% (7,901)
Provincial	19% (3,915)	24% (13,883)	29% (13,861)	30% (17,410)	33% (16,929)	41% (8,272)
Country	75% (15,220)	67% (38,326)	58% (27,423)	44% (25,122)	32% (16,591)	21% (4,214)
Field size (starters)						
Median (IQR)	10 (8, 12)	11 (8, 12)	11 (9, 12)	11 (9, 13)	11 (9, 13)	11 (9, 13)
Race distance (metres)						
Median (IQR)	1200 (1100, 1400)	1200 (1100, 1400)	1210 (1100, 1410)	1275 (1100, 1500)	1300 (1200, 1600)	1350 (1200, 1600)
Track rating						
Fast	6% (1,151)	4% (2,419)	4% (1,899)	2% (1,050)	1% (378)	0.03% (6)
Good	69% (14,045)	67% (38,503)	64% (30,583)	63% (36,473)	60% (30,751)	50% (10,232)
Dead	13% (2,589)	16% (8,947)	17% (7,960)	19% (10,761)	21% (11,022)	27% (5,542)
Slow	7% (1,430)	7% (4,019)	8% (3,964)	9% (5,331)	10% (5,068)	12% (2,461)
Heavy	5% (1,034)	6% (3,216)	7% (3,185)	7% (3,913)	8% (4,210)	11% (2,162)

Notes: for continuous variables the median and interquartile range (IQR) are presented; for categorical variables the percentage rides (number of rides) are presented.

Study factor	Category of experience (number of career rides)					
	< 50 rides	**50 – 249 rides**	**250 – 499 rides**	**500 – 999 rides**	**1000 – 1999 rides**	**≥ 2000 rides**
Track type						
Turf	87% (17,666)	90% (51,551)	93% (44,449)	94% (53,937)	97% (50,023)	98% (19,960)
Synthetic	1% (103)	1% (490)	1% (662)	1% (700)	2% (779)	2% (424)
Sand/dirt	12% (2,470)	9% (5,072)	5% (2,475)	5% (2,887)	1% (618)	0.01% (3)
Weather conditions						
Sunny	79% (16,058)	78% (44,188)	75% (35,744)	74% (42,091)	71% (36,220)	66% (13,301)
Fine	18% (3,645)	19% (10,915)	21% (9,893)	22% (12,510)	22% (11,460)	24% (4,762)
Overcast	3% (523)	3% (1,746)	4% (1,736)	4% (2,512)	6% (3,216)	10% (1,997)
Shower/storm	0.2% (31)	0.2% (118)	0.3% (135)	0.3% (175)	1% (256)	1% (198)

Notes: for continuous variables the median and interquartile range (IQR) are presented; for categorical variables the percentage rides (number of rides) are presented.

Table 6-3: Career rides of new apprentices commencing their race riding career between 2002/03 to 2008/09 racing seasons

Study factor	Falls	Rides	Falls per 100 rides	Hazard ratio (95% CI)*
Jockey experience (career rides)				
< 50 rides	158	19,917	0.79	1.00
50 – 249 rides	395	57,280	0.69	0.74 (0.51, 1.07)
250 – 499 rides	253	47,693	0.53	0.48 (0.32, 0.73)‡
500 – 999 rides	260	57,629	0.45	0.41 (0.26, 0.63)§
1000 – 1999 rides	188	51,495	0.37	0.26 (0.16, 0.42)§
≥ 2000 rides	57	20,435	0.28	0.16 (0.09, 0.28)§
				p<0.001 for trend

* HR (95% CI) = hazard ratio (95% confidence interval); † p<0.05, ‡ p<0.01, § p<0.001

In multivariable analysis, significant predictors of falls were having had less career rides (p<0.001 for trend), riding in maiden (HR 1.61; 95% CI 1.32, 1.95; p>0.001) or class races (HR 1.24; 95% CI 1.02, 1.50; p=0.029) compared to open and restricted races, fewer previous starts by the horse (HR 0.97; 95% CI 0.96, 0.98; p<0.001), drier track rating (HR 0.85; 95% CI 0.80, 0.91; p<0.001), less than 8 starters in the race compared to greater than 12 starters (HR 1.33; 95% CI 1.10, 1.60; p=0.003) and sprint races compared to middle distance races (HR 1.17; 95% CI 1.04, 1.33; p=0.012). None of the interactions were significant in the multivariable model.

To investigate whether the three factors that increased risk of falling for least experienced jockeys also differentiated the hazard of apprentice jockeys from that of their more experienced counterparts, the analyses were expanded to include mid-career jockeys and late-career jockeys. The expanded dataset included 1,375 injuries and 5,314 falls by all jockeys, from 1,293,423 flat race rides in 129,710 flat races and 17,918 race meetings. The effects of lower grade races (interaction p=0.038) and less prize money at stake (interaction p=0.048) were more pronounced for jockeys at earlier career stages. The interaction with race distance was in the direction of increased risk of falls in sprint races at later career stages, not the reverse as was the case in the apprentice jockey analyses, but did not reach statistical significance (p=0.469). Two additional factors were found to vary across career stage: the effects of riding horses with fewer previous starts (interaction 0=0.045) and of riding on drier tracks (interaction p=0.008) were more pronounced for earlier career jockeys (**Table 6-5** and **Table 6-6**).

Table 6-4: Univariable hazard ratios for falls by apprentice jockeys who commenced flat race riding during the study period, stratified by number of career rides.

	Category of experience (number of career rides)					
Study factor	**< 50 rides**	**50-249 rides**	**250-499 rides**	**500-999 rides**	**1000-1999 rides**	**≥ 2000 rides**
Jockey age at commencement of career						
< 18yo	1.00	1.00	1.00	1.00	1.00	1.00
18 - 21yo	0.80 (0.53, 1.22)	1.08 (0.85, 1.38)	1.27 (0.93, 1.72)	1.53 (1.15, 2.03)‡	1.57 (1.11, 2.22)†	0.53 (0.16, 1.78)
≥ 22yo	1.21 (0.79, 1.86)	1.10 (0.85, 1.44)	1.59 (1.13, 2.23)‡	1.42 (0.97, 2.06)	1.55 (0.97, 2.49)	0.35 (0.09, 1.31)
	p=0.340	*p=0.458*	*p=0.007*	*p=0.028*	*p=0.017*	*p=0.155*
Sex of jockey						
Male	1.00	1.00	1.00	1.00	1.00	1.00
Female	0.99 (0.70, 1.38)	1.15 (0.94, 1.42)	0.93 (0.70, 1.24)	1.11 (0.84, 1.46)	0.87 (0.58, 1.30)	0.61 (0.39, 0.97)†
Previous rides this meeting						
0 rides	1.00	1.00	1.00	1.00	1.00	1.00
1-2 rides	1.01 (0.71, 1.43)	0.70 (0.57, 0.86)‡	0.85 (0.63, 1.15)	0.73 (0.54, 0.97)†	0.77 (0.50, 1.18)	2.69 (1.31, 5.52)‡
≥ 3 rides	1.22 (0.73, 2.03)	0.59 (0.45, 0.79)§	0.80 (0.59, 1.10)	0.65 (0.47, 0.90)†	0.74 (0.48, 1.14)	1.03 (0.45, 2.36)
	p=0.457	*p=0.001*	*p=0.223*	*p=0.029*	*p=0.284*	*p=0.452*
Previous horse starts						
≥ 30 starts	1.00	1.00	1.00	1.00	1.00	1.00
15 – 29 starts	1.17 (0.62, 2.22)	1.31 (0.84, 2.04)	1.29 (0.75, 2.22)	0.98 (0.59, 1.64)	1.46 (0.76, 2.78)	4.88 (0.38, 62.64)
10 – 14 starts	1.67 (0.83, 3.36)	1.71 (1.09, 2.69)†	1.62 (0.91, 2.88)	1.85 (1.09, 3.13)†	1.20 (0.54, 2.66)	4.96 (0.42, 58.75)
5 – 9 starts	1.88 (0.96, 3.66)	2.97 (2.00, 4.42)§	2.40 (1.41, 4.08)‡	1.83 (1.09, 3.10)†	2.56 (1.39, 4.71)‡	3.64 (0.49, 26.71)
< 5 starts	2.23 (1.15, 4.29)†	3.87 (2.62, 5.73)§	3.74 (2.28, 6.14)§	2.98 (1.90, 4.68)§	3.06 (1.84, 5.08)§	7.41 (0.94, 58.42)
	p=0.007	*p<0.001*	*p<0.001*	*p<0.001*	*p<0.001*	*p=0.039*
Horse age						
> 6yo	1.00	1.00	1.00	1.00	1.00	1.00
4-6yo	1.80 (1.05, 3.11)†	1.86 (1.21, 2.85)‡	1.89 (1.13, 3.16)†	1.14 (0.70, 1.86)	1.13 (0.60, 2.13)	1.48 (0.15, 15.14)
< 4yo	2.16 (1.17, 3.98)†	2.61 (1.69, 4.02)§	3.46 (2.04, 5.87)§	1.63 (0.99, 2.66)	1.94 (1.06, 3.53)†	2.24 (0.20, 24.51)
	p=0.011	*p<0.001*	*p<0.001*	*p=0.047*	*p=0.005*	*p=0.248*

Study factor	Category of experience (number of career rides)					
	< 50 rides	**50-249 rides**	**250-499 rides**	**500-999 rides**	**1000-1999 rides**	**≥ 2000 rides**
Horse gender						
Gelding	1.00	1.00	1.00	1.00	1.00	1.00
Entire	1.29 (0.49, 3.43)	0.87 (0.39, 1.93)	1.06 (0.45, 2.49)	1.00 (0.46, 2.16)	0.64 (0.22, 1.81)	-
Filly/mare	1.17 (0.84, 1.64)	1.26 (1.03, 1.53)†	1.05 (0.79, 1.39)	1.10 (0.87, 1.40)	1.36 (1.01, 1.85)†	1.05 (0.57, 1.93)
Race grade#						
Open/Restricted	1.00	1.00	1.00	1.00	1.00	1.00
Class	1.08 (0.66, 1.77)	1.66 (1.10, 2.49)†	1.70 (1.02, 2.83)†	1.27 (0.83, 1.93)	0.87 (0.53, 1.44)	0.58 (0.29, 1.16)
Maiden	1.85 (1.11, 3.07)†	3.27 (2.18, 4.92)§	3.22 (1.88, 5.52)§	2.16 (1.40, 3.34)‡	2.04 (1.34, 3.11)‡	1.00 (0.46, 2.17)
	p=0.003	*p<0.001*	*p<0.001*	*p<0.001*	*p<0.001*	*p=0.783*
Prize money (AU$)#						
> $25k	1.00	1.00	1.00	1.00	1.00	1.00
$10k - $25k	0.53 (0.16, 1.79)	0.96 (0.48, 1.90)	1.19 (0.60, 2.36)	1.13 (0.75, 1.72)	1.62 (1.02, 2.57)†	1.41 (0.72, 2.76)
< $10k	0.65 (0.20, 2.04)	1.32 (0.67, 2.58)	1.31 (0.65, 2.66)	1.57 (1.04, 2.36)†	1.84 (1.13, 2.99)†	1.70 (0.93, 3.13)
	p=0.759	*p=0.186*	*p=0.441*	*p=0.063*	*p=0.015*	*p=0.105*
Club level						
Metropolitan	1.00	1.00	1.00	1.00	1.00	1.00
Provincial	0.53 (0.27, 1.06)	1.11 (0.80, 1.54)	0.95 (0.59, 1.54)	1.17 (0.84, 1.64)	1.24 (0.83, 1.86)	1.11 (0.61, 2.02)
Country	0.82 (0.47, 1.44)	1.11 (0.82, 1.51)	0.74 (0.47, 1.18)	1.20 (0.88, 1.63)	1.23 (0.78, 1.95)	2.06 (0.92, 4.61)
	p=0.545	*p=0.628*	*p=0.091*	*p=0.276*	*p=0.374*	*p=0.086*
Field size (starters)						
>12 starters	1.00	1.00	1.00	1.00	1.00	1.00
8-12 starters	1.07 (0.69, 1.65)	1.01 (0.79, 1.29)	0.84 (0.63, 1.13)	1.16 (0.87, 1.54)	0.98 (0.67, 1.43)	1.09 (0.49, 2.45)
< 8 starters	1.22 (0.76, 1.98)	0.97 (0.69, 1.36)	0.99 (0.65, 1.50)	1.03 (0.67, 1.57)	1.30 (0.77, 2.19)	1.10 (0.36, 3.40)
	p=0.407	*p=0.866*	*p=0.728*	*p=0.648*	*p=0.554*	*p=0.823*

Study factor	Category of experience (number of career rides)					
	< 50 rides	**50-249 rides**	**250-499 rides**	**500-999 rides**	**1000-1999 rides**	**≥ 2000 rides**
Race distance (metres)#						
Staying (≥2200m)	1.00	1.00	1.00	1.00	1.00	1.00
Middle (1301m-2199m)	1.40 (0.19, 10.09)	1.53 (0.38, 6.12)	3.11 (0.43, 22.36)	0.99 (0.46, 2.13)	0.93 (0.35, 2.44)	1.30 (0.23, 7.28)
Sprint (≤1300m)	1.59 (0.22, 11.45)	2.56 (0.64, 10.20)	4.19 (0.58, 30.19)	1.35 (0.63, 2.88)	1.17 (0.46, 3.00)	1.38 (0.26, 7.31)
	p=0.401	*p<0.001*	*p=0.007*	*p=0.041*	*p=0.277*	*p=0.694*
Track rating						
Heavy	1.00	1.00	1.00	1.00	1.00	1.00
Slow	0.51 (0.15, 1.80)	1.28 (0.71, 2.31)	1.17 (0.64, 2.17)	2.59 (0.91, 7.35)	3.11 (1.17, 8.23)†	0.69 (0.12, 4.04)
Dead	1.11 (0.48, 2.59)	1.24 (0.76, 2.04)	0.73 (0.40, 1.35)	3.42 (1.27, 9.19)†	2.57 (0.99, 6.72)	2.53 (0.81, 7.90)
Good	1.09 (0.52, 2.29)	1.45 (0.88, 2.39)	1.00 (0.62, 1.62)	3.20 (1.29, 7.93)†	3.01 (1.28, 7.09)†	2.41 (0.82, 7.06)
Fast	2.52 (1.11, 5.71)†	2.21 (1.19, 4.12)†	1.49 (0.73, 3.03)	2.86 (0.89, 9.22)	0.00 (0.00, 0.00)§	-
	p=0.044	*p=0.039*	*p=0.610*	*p=0.015*	*p=0.070*	*p=0.005*
Track type						
Turf	1.00	1.00	1.00	1.00	1.00	1.00
Synthetic	1.23 (0.19, 7.90)	0.92 (0.32, 2.65)	-	0.77 (0.18, 3.24)	1.25 (0.26, 5.92)	-
Sand/dirt	1.27 (0.81, 2.00)	1.16 (0.87, 1.55)	1.02 (0.60, 1.72)	1.00 (0.58, 1.70)	0.36 (0.10, 1.25)	-
Weather conditions						
Sunny	1.00	1.00	1.00	1.00	1.00	1.00
Fine	0.80 (0.53, 1.23)	0.89 (0.67, 1.19)	0.95 (0.67, 1.34)	0.79 (0.60, 1.06)	0.68 (0.48, 0.97)†	0.69 (0.35, 1.34)
Overcast	0.49 (0.12, 1.99)	0.82 (0.48, 1.41)	0.53 (0.22, 1.26)	0.53 (0.26, 1.08)	0.97 (0.51, 1.85)	1.04 (0.22, 4.92)
Shower/storm	-	1.26 (0.18, 8.65)	2.59 (0.56, 11.84)	1.46 (0.26, 8.20)	0.91 (0.18, 4.57)	-

* HR (95% CI) = hazard ratio (95% confidence interval); † p<0.05, ‡ p<0.01, § p<0.001; # Interaction effects: race grade (p=0.046), prize money at stake (p=0.009), race distance (p=0.051).

Table 6-5: Univariable hazard ratios for falls by jockeys, stratified by stage of career.

	Stage of career		
Study factor	**Early career HR (95% CI)***	**Mid career HR (95% CI)***	**Late career HR (95% CI)***
Jockey sex			
Male	1.00	1.00	1.00
Female	1.05 (0.90, 1.23)	1.00 (0.84, 1.19)	1.14 (0.86, 1.52)
Previous rides this meeting			
0 rides	1.00	1.00	1.00
1-2 rides	0.79 (0.69, 0.89)§	0.83 (0.76, 0.92)§	0.90 (0.78, 1.03)
≥ 3 rides	0.68 (0.59, 0.80)§	0.74 (0.66, 0.83)§	0.65 (0.55, 0.77)§
	p<0.001	*p<0.001*	*p<0.001*
Winning strike rate (%)			
≥11% winners	1.00	1.00	1.00
9-10% winners	0.97 (0.83, 1.13)	1.08 (0.93, 1.24)	1.32 (1.09, 1.61)‡
7-8% winners	1.08 (0.91, 1.29)	1.14 (1.00, 1.30)	1.35 (1.13, 1.62)‡
<7% winners	1.21 (1.02, 1.43)†	1.09 (0.92, 1.29)	1.13 (0.96, 1.34)
	p= 0.026	*p= 0.126*	*p= 0.029*
Race grade#			
Open/restricted	1.00	1.00	1.00
Class	1.30 (1.08, 1.57)‡	1.02 (0.89, 1.18)	1.22 (1.05, 1.43)†
Maiden	2.49 (2.08, 2.98)§	1.86 (1.61, 2.14)§	2.04 (1.74, 2.39)§
	p<0.001	*p<0.001*	*p<0.001*
Previous starts by horse			
≥ 30 starts	1.00	1.00	1.00
15 – 29 starts	1.28 (1.01, 1.61)†	1.16 (0.94, 1.44)	0.90 (0.69, 1.18)
10 – 14 starts	1.60 (1.27, 2.02)§	1.39 (1.09, 1.77)‡	1.33 (0.99, 1.79)
5 – 9 starts	2.27 (1.81, 2.85)§	1.46 (1.16, 1.83)‡	1.31 (0.98, 1.76)
< 5 starts	3.17 (2.55, 3.93)§	2.39 (1.92, 2.98)§	2.02 (1.53, 2.66)§
	p<0.001	*p<0.001*	*p<0.001*
Horse age			
> 6yo	1.00	1.00	1.00
4-6yo	1.56 (1.25, 1.94)§	1.25 (1.04, 1.51)†	1.22 (0.97, 1.54)
< 4yo	2.22 (1.77, 2.77)§	1.91 (1.58, 2.32)§	1.64 (1.29, 2.08)§
	p<0.001	*p<0.001*	*p<0.001*
Horse sex			
Gelding	1.00	1.00	1.00
Entire	0.95 (0.65, 1.39)	0.90 (0.67, 1.22)	1.24 (0.87, 1.78)
Filly/mare	1.17 (1.05, 1.31)‡	1.07 (0.97, 1.17)	1.10 (0.96, 1.25)
Club level			
Metropolitan	1.00	1.00	1.00
Provincial	1.15 (0.95, 1.39)	1.31 (1.14, 1.50)§	1.23 (1.02, 1.47)†
Country	1.20 (1.00, 1.46)	1.40 (1.23, 1.59)§	1.25 (1.06, 1.47)‡
	p=0.065	*p<0.001*	*p=0.013*

	Stage of career		
Study factor	**Early career HR (95% CI)***	**Mid career HR (95% CI)***	**Late career HR (95% CI)***
Prize money at stake			
> $25k	1.00	1.00	1.00
$10k - $25k	1.33 (1.06, 1.67)†	1.23 (1.05, 1.45)†	1.20 (0.97, 1.50)
< $10k	1.81 (1.43, 2.30)§	1.58 (1.35, 1.85)§	1.49, 1.22, 1.81)§
	p<0.001	*p<0.001*	*p<0.001*
Field size			
>12 starters	1.00	1.00	1.00
8-12 starters	1.03 (0.90, 1.18)	1.10 (1.00, 1.22)	1.10 (0.95, 1.28)
< 8 starters	1.10 (0.92, 1.33)	1.12 (0.97, 1.30)	1.07 (0.88, 1.30)
	p=0.316	*p=0.052*	*p=0.359*
Race distance			
Staying (≥2200m)	1.00	1.00	1.00
Middle (1301m-2199m)	1.26 (0.77, 2.07)	1.58 (1.11, 2.26)†	1.34 (0.79, 2.27)
Sprint (≤1300m)	1.82 (1.11, 2.97)†	2.30 (1.61, 3.27)§	2.14 (1.27, 3.59)‡
	p<0.001	*p<0.001*	*p<0.001*
Track rating			
Heavy	1.00	1.00	1.00
Slow	1.46 (1.04, 2.06)†	1.14 (0.89, 1.47)	0.82 (0.55, 1.22)
Dead	1.50 (1.10, 2.04)‡	1.30 (1.06, 1.59)†	1.07 (0.77, 1.48)
Good	1.67 (1.28, 2.19)§	1.43 (1.17, 1.74)‡	1.05 (0.79, 1.41)
Fast	2.76 (1.92, 3.95)§	2.00 (1.49, 2.70)§	1.19 (0.80, 1.79)
	p<0.001	*p<0.001*	*p=0.193*
Track type			
Turf	1.00	1.00	1.00
Synthetic	0.76 (0.41, 1.39)	0.59 (0.31, 1.15)	0.58 (0.20, 1.72)
Sand/dirt	1.22 (0.99, 1.50)	1.45 (1.19, 1.75)§	1.01 (0.81, 1.26)
Weather conditions			
Sunny	1.00	1.00	1.00
Fine	0.81 (0.70, 0.94)‡	0.89 (0.80, 0.99)†	0.88 (0.75, 1.04)
Overcast	0.71 (0.51, 0.99)†	0.73 (0.58, 0.93)†	0.90 (0.64, 1.29)
Shower/storm	1.76 (0.81, 3.82)	1.71 (0.82, 3.58)	1.26 (0.44, 3.64)

* HR (95% CI) = hazard ratio (95% confidence interval); † p<0.05, ‡ p<0.01, § p<0.001. # Interaction effects: race grade (p=0.038), previous starts by horse (p=0.045), prize money at stake (p=0.048), track rating (p=0.008).

Table 6-6: Falls, rides and fall rates for key variables that interacted significantly with stage of career (early, mid or late career).

	Stage of career								
	Early career			Mid career			Late career		
Study factor	**Falls**	**Rides**	**Falls per 100 rides**	**Falls**	**Rides**	**Falls per 100 rides**	**Falls**	**Rides**	**Falls per 100 rides**
Race grade#									
Maiden	619	76,728	0.81	894	153,520	0.58	455	95,783	0.48
Class	547	131,592	0.42	742	231,687	0.32	440	154,812	0.28
Open/restricted	145	46,127	0.31	407	128,351	0.32	188	81,392	0.23
Previous starts by horse#									
< 5 starts	498	58,623	0.85	995	175,040	0.57	494	107,361	0.46
5 – 9 starts	298	47,517	0.63	393	112,067	0.35	215	70,901	0.30
10 – 14 starts	167	38,050	0.44	249	75,236	0.33	151	48,524	0.31
15 – 29 starts	229	67,747	0.34	303	108,024	0.28	152	73,493	0.21
≥ 30 starts	119	42,512	0.28	103	43,229	0.24	71	31,739	0.22
Prize money at stake#									
< $10k	824	129,767	0.63	1,146	244,099	0.47	637	171,825	0.37
$10k - $25k	390	91,724	0.43	641	181,901	0.35	314	105,644	0.30
> $25k	97	32,950	0.29	255	87,550	0.29	131	54,517	0.24
Track rating#									
Fast	69	6,903	1.00	101	16,297	0.62	48	12,404	0.39
Good	870	160,587	0.54	1,378	332,668	0.41	735	222,449	0.33
Dead	215	46,821	0.46	333	89,117	0.37	176	53,687	0.33
Slow	103	22,273	0.46	135	41,799	0.32	65	24,712	0.26
Heavy	54	17,720	0.30	95	33,552	0.28	59	18,630	0.32

Interaction effects: race grade (p=0.038), previous starts by horse (p=0.045), prize money at stake (p=0.048), track rating (p=0.008).

In multivariable analysis, significant predictors of falls were stage of career ($p<0.001$), race grade ($p<0.001$), previous starts by the horse ($p<0.001$), track rating ($p<0.001$), field size ($p<0.001$), race distance ($p<0.001$) and jockey winning strike rate ($p=0.001$). Jockeys riding in races held on synthetic race tracks had a hazard 0.54 (95% CI 0.36, 0.81; $p=0.003$) times lower and those riding on dirt/sand tracks had a hazard 1.21 (95% CI 1.07, 1.37; $p=0.003$) times higher, than those riding on turf tracks. Jockeys riding in races under showery or stormy weather conditions had a hazard 1.77 (95% CI 1.10, 2.83; $p=0.018$) times higher than those riding under sunny weather conditions. Interactions between stage of career and previous starts by the horse ($p=0.048$) and between stage of career and track rating ($p=0.006$) remained significant once adjusting for all other factors in the model. The interactions between stage of career and race grade, and between stage of career and prize money at stake, were not statistically significant.

6.5 Discussion

This is the first study to comprehensively investigate the effect of jockey experience on falls by thoroughbred racing jockeys. It expands and elaborates on findings from the previous study [11] on falls to jockeys in flat races that was conducted in a dataset too small to allow a thorough investigation of the contribution of jockey inexperience to falls. The factors found to be associated with falls by inexperienced jockeys were those previously determined to predict falls and injuries by jockeys irrespective of career stage.

With the expanded dataset formed by augmenting data for racing seasons 2002/03 through 2005/06 with additional data for the racing seasons 2006/07, 2007/08 and 2008/09, it was possible to define a cohort of apprentice jockeys and follow their careers from their first race ride. This analysis revealed that the apprentice jockeys commenced riding generally older horses in lower prize money events particularly maiden or class races over shorter distances at country race tracks, and progressed to riding younger horses in stronger open/restricted events more often in larger fields over longer distances and on metropolitan race tracks. The finding of a lesser proportion of rides by least experienced apprentice jockeys on heavier tracks, when the more recent race seasons have been generally wetter, was explained by the substantial increase in monthly frequency of race rides as the jockeys became more experienced. The most experienced jockeys more frequently rode on heavier tracks because they had more race rides in the wetter seasons. Cox proportional hazards modelling was used to estimate hazard ratios for falls at levels of study factors that may contribute to falls. This confirmed that apprentice experience was

inversely and strongly associated with the probability of falls. Other factors found to be associated with falls by apprentice jockeys were having had fewer previous rides this meeting, riding horses with a fewer number of previous starts, riding younger horses, riding in lower race grades, riding in races with less prize money at stake, riding in shorter distance races and riding on drier tracks. With the exception of previous starts by the horse, which was based on information not available at the time of the earlier analysis [11], these were shown in the previous investigation [11] to be associated with falls by jockeys at all career stages.

The next step was to investigate which of those factors varied differentially in strength of association with category of jockey experience. Factors that had a more pronounced hazard ratio in the earlier stages of the race riding career of an apprentice jockey were lower grade races, races with less prize money at stake and races over shorter distances. Each of these interactions was attenuated by adjusting for other indicators of horse inexperience in multivariable analysis, and none remained statistically significant. These results suggest that apprentice jockeys are particularly prone to falls early in their career when riding less well-performed horses in sprint races.

To test the generalisability of the findings, and to possibly identify other factors that were differentially associated with falls by early-career jockeys, the hazard ratios for early-career jockeys were compared to those for mid and late career jockeys. This analysis confirmed that lower race grade and less prize money at stake were risk factors that are more pronounced for early career jockeys. The findings for race distance were not confirmed, however. Other factors identified in this analysis as imposing greater hazard for early career jockeys were riding horses with fewer previous starts and riding in races on drier tracks. Fully adjusted for all other factors, these were the only two factors with effects that varied in a statistically significant manner with career stage.

The results in relation to race grade, less prize money at stake and horses with fewer previous starts, and particularly the finding that these factors were accounted for by alternative indicators of horse inexperience in adjusted analysis, suggest that inexperience and/or inability of the horse contributes significantly to the risk of falls by inexperienced riders. The results for race grade echo the findings in the previous study [11], where an increased fall incidence rate was observed for apprentice jockeys riding in lower grade races. The need to investigate specific skills that experienced riders use when riding

inexperienced horses was proposed in the report of that study [11], and the need for a thorough study of the physiological attributes of successful riders has also been highlighted (see **Chapter 7**) . It has also been recommended that consideration be given to restricting apprentice jockeys with little race riding experience from riding difficult or unruly horses, especially those that have not yet won a race (maiden) or that have had few previous race starts. It is conceded that placing such restrictions on jockeys may impact on the amount of money able to be made in race riding fees and prize money by those jockeys, the experience to be gained when riding such horses, and the weight allowances that the trainers of such horses may be able to utilise (apprentices with fewer wins have a higher weight claim).

The findings in respect of increased hazard for earlier career jockeys when riding on drier tracks reflect an earlier conclusion [11] that faster speeds and tighter racing may contribute to increased fall rates in flat racing. We observed a higher hazard ratio for early career jockeys riding in races conducted on drier tracks, with noticeably greater fall rates on faster tracks. To further investigate this issue, objective information on the state of the track is required [11].

This study adds to the limited information available on risk factors for falls by jockeys, particularly in respect of less-experienced jockeys, and is the first study to report comprehensively on the effect of jockey experience on rates of race-day falls. The strengths of this study were complete ascertainment of race information and high ascertainment of falls from the 96% of stewards reports that were able to be obtained, its large size that permitted close investigation of risk factors within strata of other factors, and the objective nature of the information on jockey and horse experience. Furthermore, the rich data collection made it possible to investigate a wide range of study factors as predictors of falls in their own right and as confounders or effect modifiers.

There are some limitations of this study that should be borne in mind. This study allows conclusions about associations, but not about causation. That it was possible to trace jockeys over seven race seasons, and to observe directly the inferred effects of their experience over time without relying on recall or hearsay, increases confidence in the findings of this study. Whilst there is little cause to suspect bias in the information obtained, the possibility of random error in the measurements of outcome and study factors cannot be discounted. Additional information on jockey experience – such as

previous skills and knowledge obtained whilst working with horses prior to commencing their apprenticeship, experience gained through track-work riding and barrier trial rides, and on career history including sanctions for careless riding – would have strengthened this study. Further, as noted previously [11], information was not available on physiological attributes of the jockeys or on extraneous factors such as the size of the crowd at the race meeting or race day procedures that could be important risk factors, confounders or effect modifiers.

6.6 Conclusions

This is the first epidemiological study to investigate experience-related risk factors for falls to jockeys in thoroughbred flat races. It was confirmed that apprentice experience was inversely and strongly associated with the probability of falls. Factors that increased the hazard associated with inexperience appeared to be alternative indicators of horse inexperience. In a comparison of jockeys at three different career stages, horse experience was confirmed as increasing the hazard for early career jockeys. If confirmed, these results could form the basis for developing evidence-based apprentice training programs and for introduction of policy restricting early-career jockeys from riding in situations that have been confirmed to impose high risk on inexperienced jockeys.

6.7 Postscript

In this chapter a range of factors associated with falls by inexperienced thoroughbred racing jockeys riding in flat races were identified. These analyses were conducted using routinely collected data. In the next chapter (**Chapter 7**), a report is presented of a pilot study in which personalised measurements of the physiological attributes are made and tested for predictive validity.

6.8 References

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